

# HOW DATA COLLECTION CAN HELP IN UNDERSTANDING BUILDINGS IN OPERATION

**Peter Dickinson**

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## **SUMMARY OF**

## **ACTIONS TOWARDS SUSTAINABLE OUTCOMES**

### **Environmental Issues/Principal Impacts**

Wastage of energy leads to excess consumption of natural resources as well as unnecessary pollution. Data collection can assist in reducing this energy wastage through some of the following measures:

- Keeping building management and tenants continually aware of energy use.
- Allowing for fast-track approval and implementation of energy efficiency improvements.
- Providing a watchdog over control systems, maintenance and house keeping.
- Detecting theft and anomalies.

### **Basic Strategies**

*In many design situations, boundaries and constraints limit the application of cutting EDGe actions. In these circumstances, designers should at least consider the following:*

- Reviewing monthly invoices, entering key consumption data into spreadsheets and providing summary reports to management of long term trends and specific benchmarks (Key Performance Indicators).
- Receiving time-of-use data (15 minute or 30 minute data) from utilities for management reports – adding more detail to trends and analysis.
- Setting up trends on the building management system for indoor conditions, large plant and any installed metering.

### **Cutting EDGe Strategies**

- Install smart metering throughout the building in strategic locations.
- Create systems for personnel and software that assess smart meter data regularly.
- Create a defined role for a staff member as 'energy manager'.
- Maintain a strategic energy management plan based on regular energy reports.
- Benchmark energy performance against other similar organisations locally, nationally and internationally.

### **Synergies and References**

- Australian Building Greenhouse Rating Scheme: [www.ABGR.com.au](http://www.ABGR.com.au)
  - Australiana Energy Performance Contracting Association: [www.AEPCA.asn.au](http://www.AEPCA.asn.au)
  - Australian Bureau of Meteorology: [www.BOM.gov.au](http://www.BOM.gov.au)
  - NSW Department of Energy, Utilities and Sustainability: [www.deus.nsw.gov.au](http://www.deus.nsw.gov.au)
  - Energy SA: [www.energy.sa.gov.au](http://www.energy.sa.gov.au)
  - Sustainable Energy Authority of Victoria: [www.seav.vic.gov.au](http://www.seav.vic.gov.au)
  - BDP *Environment Design Guide*: GEN 65
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*Regular data collection of a building's energy and water use provides building owners/operators with a real understanding and insight into the actual operation of their buildings. Building owners can then use this knowledge to achieve a range of significant benefits such as energy and dollar savings of up to 40 per cent which leads to an inherent reduction in pollution through increased efficiency. Other more subtle benefits include an ongoing 'awareness' throughout the building, better stakeholder relationships and good corporate citizenship. This note will examine the various forms of information that are readily available, as well as other sources that can provide further data. Using this data, the note then explores some of the ways that information can be effectively utilised.*

## 1.0 INTRODUCTION

Many building operators rely on traditional means of gauging building operation based on information such as tenant feedback as well as scheduled (and unscheduled!) maintenance. The more traditional means do not, however, typically give insight into how efficiently the building runs or what potential might exist for better performance. Given the cost of energy and the higher potential cost of poor corporate citizenship, a pro-active approach in ascertaining actual building operation is imperative for any building operator.

Simply keeping occupants comfortable does not indicate that a building performs optimally – in fact tenant comfort often comes at an unnecessary cost to building energy performance – especially where maintenance has been limited and plant is left to struggle to meet stringent occupant requirements. The best indicator of how efficiently a building's plant meets the needs of its occupants is the energy consumption data. The cost of operating a building, the amount of pollution that is created through energy production for the building and the natural resources required for meeting the needs of the occupants all relate back to energy and water consumption information.

A bevy of data relating to building operation and energy consumption is available to the typical building manager. Much of it is close at hand with more data available if one knows where to find it and, more importantly, how to use it. A proactive process of collection and dissemination is required if piles of meaningless data are to become effective information that leads to real action.

## 2.0 BACKGROUND

Data collection provides real evidence as to a building's operation in terms of plant operation and occupant activities. The introduction of intelligent data collection can lead to energy savings typically in the range of 5-15 per cent in an already well run commercial building. In fact, savings of up to 40 per cent are possible in new buildings in which commissioning has been very basic. Most organisations that employ an effective system of data collection,

analysis and response exhibit a downward yearly trend in energy consumption which is the opposite of the trend exhibited in many other buildings. Hence, a five per cent saving through better energy analysis may actually be a relative 10 per cent saving when considering a potential five per cent yearly increase in building energy use.

There are many areas from which these savings are drawn. The question of which areas provide the best opportunities at the least cost is answered much more easily when up-to-date data is available. Some of both the hard (dollar) and soft benefits include:

- Keeping building management and tenants continually aware of energy use
- Allowing for fast tracked approval and implementation of energy efficiency improvements
- Providing a watchdog over control systems, maintenance and house keeping
- Detecting theft and anomalies
- Good corporate citizenship through a better ability to be transparent about energy usage and the efforts that are being undertaken to reduce the environmental footprint.

Building operation data is available from many sources such as utility invoices and from on-site control systems. Digging a little deeper may reveal other forms of useful data such as the utility's time-of-use (TOU) data and weather information from the Bureau of Meteorology – much of which can be acquired regularly at little or no cost. Using currently available information as a first step, the overall 'picture' of a building's operation can be developed. A strategy based on this information can then be formed and used to readily make initial improvements in performance.

Typically, a human system will form around the data systems in the initial stages of data collection, analysis and action. These human systems (the people going through the process) are the key to sustained success and are often forgotten in the race to install so-called 'smart metering' throughout a facility. Once the human system can match the capability of a smart metering system, an organisation is well placed to make choices about that data collection system.

### 3.0 GETTING STARTED – DATA YOU ALREADY HAVE

There is a vast amount of data available to most building operators from a variety of obvious, and not so obvious, sources. These avenues should be explored for meaningful data that can be converted to useful information. This should be done before time and effort is expended on the addition of new data generating equipment such as meters, sensors and the like. Outlined below are a few of the more obvious sources and how to utilise the available data.

#### 3.1 Utility bills

Utility bills often provide the most regular and obvious source of building performance data yet they are rarely utilised. Electricity, gas and water invoices can be used to track long term trends when key information is entered into a spreadsheet. The spreadsheet can then be used to highlight exceptions to the norm such as jumps in peak demand, etc.

The key information available from a typical electricity bill for entering into a spreadsheet includes:

- Total consumption
- Total cost
- Time-of-use consumption break-up (peak, off peak, evening/shoulder)
- Maximum electrical demand size and cost of demand charge.

The key information available from a typical gas (or water) bill for entering into a spreadsheet includes:

- Total consumption
- Total cost
- Maximum demand date and size (if on a maximum quantity type contract).

#### 3.2 Building Management System (BMS) Data

The building management system (BMS) often provides one of the central sources of building information for larger facilities. Information on a building's internal conditions is often complemented with energy information which can be logged and graphed. Spending some time with the controls technician for the building's BMS will quickly provide the building manager with a vast array of information. Some of the key areas to start looking at on the BMS include:

- Plant run times and calls such as chiller starts and stops
- Space temperature trends which will show how well the plant is meeting occupant requirements
- Metering equipment connected to the BMS
- Supply air temperature information which will indicate if plant is working harder than it needs to in given conditions.

Going beyond this initial BMS information, the building manager should start comparing BMS information with the actual operation of the building looking at factors such as:

- Control function operation, such as variable speed drive operating percentages, valve positions, chilled water temperatures and the like which can provide valuable insights into the reasonableness of control functions and the existence of maintenance and commissioning issues.
- Are leading and lagging plant running as intended (i.e. not running at the same time)?
- Are all chilled water and heating water valves closed when the BMS says they are closed? For instance, a quick check of supply temperature may reveal a very low supply temperature and the chilled water valve may be closed. In the field, the cooling coil may actually be cold indicating a stuck valve.
- Are the chillers loading up as intended? If chiller loading has been poorly programmed, cooling plant may continually switch between different chiller schedules, causing unnecessary demand peaks.

Regular, consistent checks along these lines will give the building manager a good idea as to the way the building operates and the effectiveness of current maintenance practices. It is far easier to determine many maintenance issues through the BMS than accessing often very difficult or sensitive areas of the building.

If there is no energy related information available through the BMS, independent data should be sought to complement the intelligence gained through the BMS. Without energy data, it is impossible to be completely certain that all findings are a true reflection of the building's *actual* operation. Energy data provides the building operator with a 'watch-dog' feature and from a cost point of view is one of the foundation indicators of building performance.

#### 3.3 Time of use (TOU) data

Behind the energy bill that a facility receives from its energy retailer is a body of information on the site's energy use over the billing period. This information is often referred to as time-of-use data (TOU) and it details the energy used in each time block (typically 15 or 30 minute blocks) for the month. These blocks allow the energy retailer to break up energy use into time of day usage as well as calculate total usage and maximum demand. Building on the data contained in a site's invoice, the addition of time-of-use data provides a path to much greater energy intelligence. Rather than the small number of key pieces of data on a typical utility bill, the month's usage is broken down into data in a format similar to that shown in the following example:

| Date       | Time  | kWh |
|------------|-------|-----|
| 01/01/2005 | 14:00 | 148 |
| 01/01/2005 | 14:15 | 147 |
| 01/01/2005 | 14:30 | 152 |
| 01/01/2005 | 14:45 | 140 |
| 01/01/2005 | 15:00 | 140 |
| 01/01/2005 | 15:15 | 148 |
| 01/01/2005 | 15:30 | 147 |
| 01/01/2005 | 15:45 | 148 |
| Etc ...    |       |     |

**Table 1. Example of time-of-use data**

Typically, time-of-use data is made available through the retailer's web-site and may be updated monthly (common) or even daily (less common) or is available on demand. Alternatively, the data can be made available on request to the site's account manager – their contact details are usually on the invoice for larger sites.

For smaller sites, time-of-use data is not typically available unless appropriate retail metering is in place. Time-of-use information for gas is very rare for other than the largest sites and rarer still for water data. However, gas and water utilities are actively researching methods for collecting time-of-use information which may lead to this information being more widely available in the future.

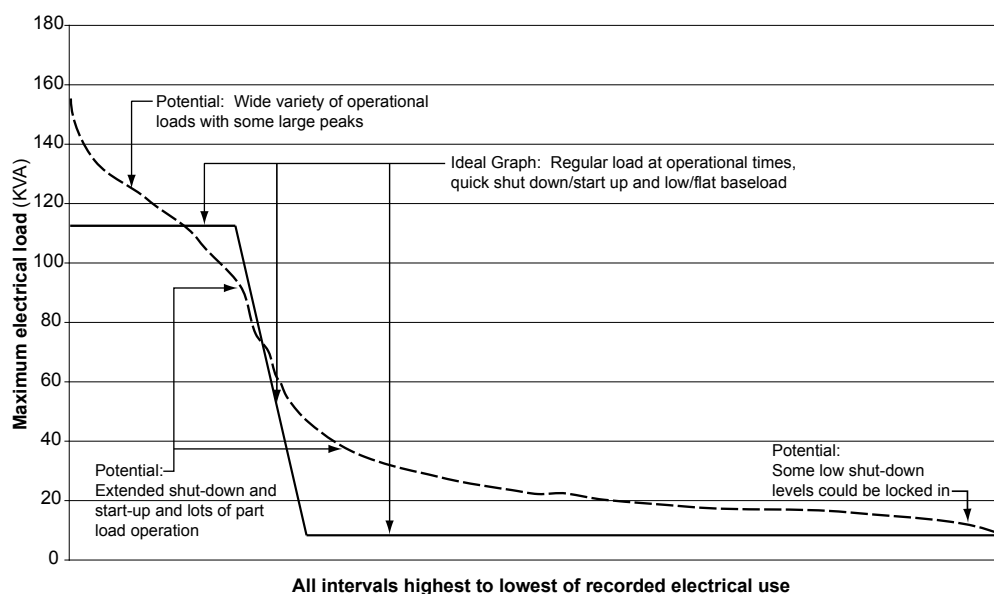
Once obtained, the data can be brought into a spreadsheet such as Excel and manipulated to provide a very high level of information. Some of the different ways of manipulating the data include:

- Simple line graph of the month's usage – This will give an idea of the general 'trend' of the month's usage but will not provide a great deal of enlightenment as to the facilities potential. The human eye cannot pick-up most faults, other than the most obvious, through a whole month profile graph.

- Weekly overlay – Each weekly block of data could be presented in overlaying line graphs – this will provide a very obvious way of detecting increases and decreases in loads at different times of the week and day.
- Load duration – By taking all available energy readings for the month, we can list them from highest to lowest and produce a load duration graph. When graphed, this provides an immediate picture as to what percentage of time the facility spends at various load levels. To the left of the graph will be a high load area and, conversely, the right side of the graph will indicate part load levels. A perfect load duration graph will show a flat high and low area and a steep transition between the two. A gentle slope will indicate a long period of time the site spends between full and no load conditions – potentially indicating extended start-up and shut-down programming (see Figure 1). A sharp 'turn-up' at the left of the graph will show a small number of demand 'spikes' which may be causing unnecessary demand charges, whereas a sharp 'turn-down' to the right of the graph will indicate some very low load conditions that should be attempted to be 'locked in'.

## 4.0 BUILDING FURTHER – DATA YOU MAY NOT KNOW YOU HAVE

Beyond the more typical sources of data lie sources that can add a new dimension to the intelligence already outlined in section two. These data sources include the Bureau of Meteorology, industry benchmarks, state government departments and the service providers who operate at the site. This additional information will allow the energy manager to build on the knowledge already gained as well as better determine areas of fault and areas of potential.



**Figure 1. Load duration graph**

## 4.1 Bureau of Meteorology (BoM)

The Bureau of Meteorology has a vast array of data collecting devices installed across Australia. A large amount of this data is available on their website ([www.bom.gov.au](http://www.bom.gov.au)). In addition to the time-of-use data collected, a building manager would then be able to add further intelligence to the operation of building plant. Typically, a great use of weather information is to produce an 'X-Y Scatter' graph to:

- compare daily total electricity usage with the daily average temperatures for the month
- compare daily maximum electrical demand with the daily maximum temperatures for the month
- compare daily total usage of gas with the daily minimum temperatures for the month.

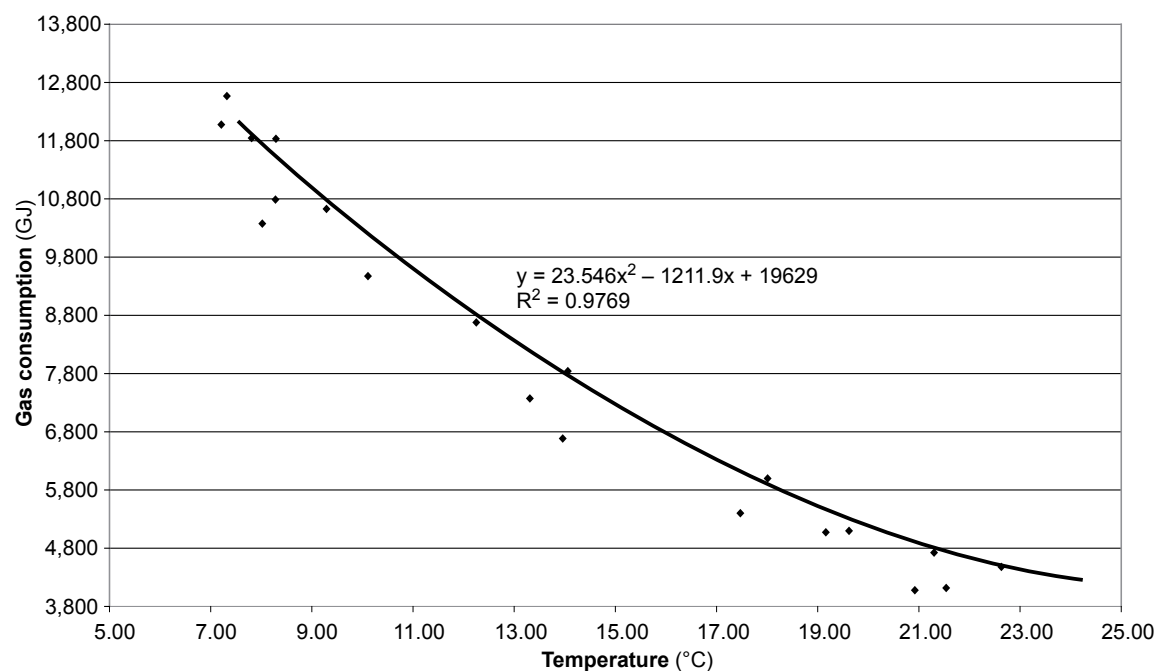
Once an XY scatter graph has been generated, a line of best fit can be inserted. A line of best fit may simply be a straight line if there is a very linear relationship between the two variables in question. Quite often, however, the user will need to use a polynomial line of best fit (a commonly available option when inserting a line of best fit) to better fit a mathematical model to the data. A second order polynomial (as shown in Figure 2) will often give a good level of fit (i.e. an  $R^2$  value as close as possible to 1) without the need for an overly complex mathematical equation. This final equation will provide the energy manager with an immediate 'finger-print' as to how the facility responds to different temperatures. This finger print could be printed out as a quick reference for the building manager. Taking the temperature information for the day, the building manager will be quickly able to predict the day's total, base and peak consumption of energy or, conversely, know if the given energy consumption figures fall within the expected region.

Obviously, this information is of most use in the analysis of a building's services (heating, ventilation and air conditioning) load as tenant (light and power) load is typically independent of ambient conditions.

## 4.2 Industry benchmarks

Professional bodies such as the Property Council of Australia (PCA), the Facilities Management Association (FMA) and the Australian Institute of Refrigeration Air Conditioning and Heating (AIRAH) can potentially provide a great deal of information to building industry professionals by supplying research information, contacts for owners of similar buildings and relevant information from other parts of the world. This data is typically in the form of industry benchmarks and covers many areas beyond energy management. Site managers should contact these organizations for information that relates to their industry or region. Such information includes:

- Energy intensity – benchmarks such as the Commonwealth Government's benchmarks of 500 mega joules of energy consumed per square metre of occupied space for building central services (plant, etc) or 10,000 mega joules per person for tenant light & power consumption.
- Production intensity – energy or water usage per 'widget' produced. One example might be the amount of water consumed per litre of soft drink produced or the amount of energy required per ream of paper produced.
- Australian Building Greenhouse Rating (ABGR) for other local buildings or similar buildings across Australia.



**Figure 2. A typical gas consumption versus minimum temperature XY scatter graph**

### 4.3 State energy departments

State energy departments across Australia are extremely keen to help industry improve their energy efficiency. Departments such as Energy SA (South Australia), the Sustainable Energy Authority of Victoria (SEAV) and the Department of Energy, Utilities and Sustainability (NSW – formerly SEDA) can provide advice and direction to building operators. For operators of more energy intensive facilities, more tailored advice is often available and some subsidies are available for efficiency improvement projects. As these departments and their relevant funding are subject to continual change, it is recommended that their websites be checked for the most up-to-date information.

As far as data collection is concerned, state energy departments may have access to a variety of benchmark data from other buildings. This data is becoming increasingly more formalised through benchmarking schemes such as the Australian Building Greenhouse Rating (ABGR) scheme for commercial buildings.

## 5.0 FORMING A STRATEGY

As all available information is gleaned from various relevant sources, the 'people systems' surrounding the energy management system will have taken shape. This 'people system' refers to the regular activities that centre around the data collection system and will typically be conducted by one person, although for larger facilities it may be a team or committee. People systems are responsible for successfully taking data through the stages of collection and verification to the final stages of real action.

One of the key objectives for the building (energy) manager is to combine their knowledge of the site with the compiled performance information outlined above to develop a set of meaningful (key) performance indicators or KPI's. On the one hand, these may be as simple as some of the indicators outlined above, such as energy intensity per person or per square metre. Alternatively, specialist measures may be developed to suit the particular requirements of a building, such as the energy intensity per bed in a hospital). This benchmark could be compared with historical figures to give a year-in year-out trend or, if possible, be compared with other hospitals. More importantly, once a benchmark has been created it can be communicated to staff and/or clients who can then be actively involved in efforts to 'raise the bar' on energy performance.

Given the information that is now flowing through the system, realistic targets for energy use can be set – giving direction as to what can be achieved in the building. The dollar value of achieving the target can be easily calculated and, in turn, provides an indication of the budget that may be possible given the internal rate of return goals of the organisation. An added advantage for the building manager when setting benchmarks is that they can provide their clients with more certainty about the energy impact of particular projects. Many methods can be used for the verification of performance improvements including

reassessment of a building's ABGR (if previously undertaken) or through the use of the Australian Energy Performance Contracting Association's (AEP-CA) measurement and verification guidelines.

## 6.0 HOW TO STRATEGICALLY ADD DATA INTELLIGENCE

Through the investigation of all the available data sources outlined above, it may be obvious that there is a deficiency in the current data sources. This may be in the form of data that are unavailable or do not provide the required detail, or it may simply be that the data exists but it is inaccessible or useless in the given format. For example, data may be useless if it is only available graphically on the web or through the building's control system if the building manager requires the information in a spreadsheet format. This means the building manager may be required to set up dedicated data collection systems such as:

- Stand alone electricity, gas and water monitoring systems; or
- Additional new monitoring capability to the BMS through new interfaces, modules or simply more monitoring points.

The choice between these scenarios is most dependent on the operator. A building/energy manager without BMS access or at a site without a BMS will obviously choose a stand-alone system. Alternatively, someone who frequently uses the BMS and is comfortable in its advanced operation would probably choose to implement additional BMS capabilities. For either system, there are the following key considerations:

- Are the data converted into meaningful information or, at the very least, are they capable of being exported into a spreadsheet for more meaningful extrapolation?
- Are the data reliable and in a format that will not be lost in the event of power outages, disruptions, restarts, etc? This is especially true when the monitoring and collection of energy data is not the central role of the building management system.
- Is the cost of the system suitable given the organisation's goals and potential return?

Whichever method of adding additional capacity is chosen, it should allow for a streamlined 'fit' with the people and the systems involved in monitoring the building's operation. Some of the key issues to consider when finally adding monitoring equipment include:

- What to monitor – the question of what to monitor is central to the successful implementation of a monitoring system. Equipment should be installed to allow the most accurate indicators to be monitored. Plant and equipment that may cause anomalies should be separated out, as should any specialist functions that may adversely affect the accuracy of calculated indicators. These specialist functions may include areas such as server rooms and

- climate controlled storage rooms. As well as allowing the separation of these areas from the key focus indicators, the separated areas themselves can then become subject to their own benchmarks.
- Capability of equipment – any equipment installed should meet the current and perceived future needs of the building. For electricity metering a minimum of pulsing outputs for kilowatt hours and kilo volt amp hours should be available. In more complex sites, the energy metering should utilise the building's existing networks. Some of these formats include Lon, Modbus and TCP/IP (Ethernet). Equipment should also be sized to allow for reasonable future expansion.
  - Physical location – wherever possible locate all energy metering equipment centrally – typically at the main switchboard. This reduces the cost and complexity of communications as well as reducing the likelihood that various pieces of equipment will be 'forgotten' in the future if located in obscure positions.
  - Accessibility – any information that is generated should be readily available to those people who are utilising the information. (It is common to have various steps undertaken by different users before the information is delivered to the final user.) Any extra steps in the delivery of data to the final user increase the risk of the entire system failing in the future as intermediate users come and go.

## 7.0 CONCLUSIONS

As has been shown above, there is a great deal of data available to most building managers at no cost. Strategies have been given for converting that data into useful information. Building on the data that is available, further methodologies have been outlined to give a detailed picture of a building's actual operation. Building managers can benefit greatly from seeking out all available information first before installing any data collecting equipment (new meters, software, etc). The readily available information will allow the formation of strategies – which in turn may dictate the areas in which more data may be required.

Where more data is deemed necessary, details have been given to assist the building manager in successfully adding collection capacity that meets the needs of the building into the future.

## REFERENCES

Australian Building Greenhouse Rating Scheme:  
[www.ABGR.com.au](http://www.ABGR.com.au)

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[www.energy.sa.gov.au](http://www.energy.sa.gov.au)

Sustainable Energy Authority of Victoria:  
[www.seav.vic.gov.au](http://www.seav.vic.gov.au)

## BIOGRAPHY

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