FORUM

Energy and water monitoring for existing buildings

By Robin Archibald

ABSTRACT

This report examines the use of monitoring systems in existing commercial buildings. There are a number of drivers for the installation of monitoring systems, and these are discussed. Monitoring systems are available in many different forms and are categorised according to data source, resolution and availability.

A wide variety of monitoring systems and technologies are available and these are discussed in terms of data collection methods and user interface options. A monitoring system design process has been outlined to assist those intending to design a system for their building. Finally, case studies of monitoring systems are presented including details of system monitoring points and benefits achieved.

Key Words: Monitoring, utilities, energy, water, metering, existing buildings, commercial buildings, office buildings

INTRODUCTION

Commercial buildings in Australia spend around $4 billion each year on energy and generate more than 50 million tonnes of carbon dioxide annually1. Emissions continue to increase by 3-4% per annum . While significant progress in new building design is being achieved, with 4.5 ABGR stars and 4.0 Green Star buildings common, efficiency improvements in existing buildings are also required.

It is often quoted:

"If you can't measure it, you can't manage it"

This is largely true. Monitoring allows the current efficiency level to be identified and benchmarked against other facilities and best practice. It highlights where improvement opportunities are likely to exist and provides a means to evaluate efficiency improvements undertaken. For these reasons and more, monitoring is a vital component of any energy or water-efficiency program.

WHY MONITOR ENERGY AND WATER USAGE?

The more environmentally aware among us use monitoring systems to improve energy and water efficiency and reduce our buildings' impact on the environment. However, there are a wide range of other benefits from monitoring utility usage that are often the main driver for implementing a system.

These are outlined in Table 1:

Although it may only take one of the above benefits to justify the implementation of a monitoring system in your organisation or building, there are often several secondary benefits that can be utilised for environmental or cost benefits. Highlighting secondary benefits such as cost savings can make the business case for a monitoring system considerably more attractive.

It is also important to recognise that a monitoring system will rarely provide consumption or cost savings directly. However, a system will provide data to allow effective ongoing management of the utility and identification of saving opportunities. It is the ongoing management actions that will achieve usage and cost savings. Resources need to be allocated accordingly.

This is best achieved as part of a structured energy, water or carbon management program that can use the monitoring system to obtain multiple benefits.

WHAT IS MONITORING?

To monitor is to check, watch, observe, keep an eye on, scrutinise, examine and review!

There are many methods and levels of detail at which monitoring can be achieved. These will largely be determined by the objectives of the monitoring system, desired accuracy of information but also by availability of data, metering equipment, and implementation budgets.

Data types

For commercial buildings we are predominantly interested in the monitoring of:

- electricity
- natural gas
- water
- any other energy source (eg diesel, LPG, bottled gas)

For purposes of energy and water management, it is often desirable to monitor energy efficiency indicators (eg kWh/sq m). In such cases we may need to monitor:

- floor area
- staff numbers
- operating hours
- equipment levels
- ambient temperatures
- units of production

Table 1: Monitoring system benefits

BENEFIT	DESCRIPTION
Expenditure and budget management	Establish budgets, monitor costs against budget
Supply infrastructure management	Alleviate requirement for supply infrastructure or capacity upgrade
Demand management	Reduce peak loads, costs and load shedding
Monitor quality of electricity supply	eg voltage and harmonics to reduce supply disruption, wear and tear and equipment failures
Manage procurement	Consolidate supply contracts to reduce supply and administration costs via consolidated electronic invoicing
Invoicing tenants for usage	Cost recovery
Apportioning costs to business units	Cost management, encourage business units to take responsibility for usage and costs
Facilities management and maintenance	Alarms on supply failure, high or low equipment loads, etc
Manage utility costs	Efficiency improvements, demand management, invoice validation, verification and reconciliation, tariff analysis.
Manage environmental impact	Efficiency improvements, Greenhouse Gas (GHG) emissions, water use
Benchmarking	Compare efficiency with average and best practice eg NABERS, Green Star
Usage targets	Monitor performance against usage targets and establish "Usage Signature" for particular building to alarm unintended usage.
Compliance with government regulations or voluntary programs	eg NSW Energy and Water Plans, EEO, NGER, EPA, licence, etc
Tenant/landlord requirements	eg Government tenant requirements, accommodation guidelines, Property Council of Austrailia building classifications, etc
Reporting	Greenhouse Challenge Plus, government reporting (OSCAR), public annual environmental and triple bottom line reporting.
Marketing and competitive edge	Establish green credentials to market to public or prospective tenants

Monitoring systems can also range in scope from a single building or tenancy to an entire property portfolio.

Data source

Monitoring data is typically obtained from one of three sources listed in Table 2.

Table 2: Data source categories

DATA SOURCE	EXAMPLES
Utility Invoices	Paper or electronic invoices received from utilities
Utility Metering	Site or tenancy level metering
Sub-Metering	Functional area, building service or equipment level metering

While it is common for a monitoring system to utilise data from only one source, comprehensive systems can use data from all three sources. This can facilitate additional cost-saving initiatives such as invoice verification and reconciliation.

Data resolution

We refer to the time interval at which data is collected as "resolution". Data resolution can vary widely from real time to annual. Resolution is an important parameter for a monitoring system because it determines the benefits that can be obtained.

Data availability

Data "availability" can also vary widely, from annual to real time. It differs from resolution in that availability represents the intervals at which data is available to users. For example, meter data from an electricity retailer may have quarter hourly resolution but may only be provided in bulk once a month.

Data availability is largely determined by how monitoring is undertaken. This is discussed in more detail in the next section.

HOW DO WE MONITOR ?

Monitoring can be undertaken in many different ways, using many different technologies and software packages, both proprietary and specially developed.

Table 3: Data resolution categories

DATA RESOLUTION	APPLICATIONS
Annual	Suitable for annual reporting, eg public and TBL reporting, OSCAR, EEO, NGER. Summary level indication of portfolio or building performance.
Biannual	Primarily for reporting, biannual information can provide a forecast of full-year results.
Quarterly	Provides a basic level of ongoing monitoring while limiting data processing to four times per year to minimise costs.
Monthly	Provides a good level of ongoing monitoring but can increase costs as data processing may be required 12 times per year.
Weekly	Rarely seen as data is not readily available in weekly intervals.
Daily	Shows usage profiles over a week for analysis of weekend v weekday activity.
Hourly	Shows daily usage profiles allowing site and equipment usage patterns to be monitored and analysed.
Pseudo real time (30 min, 15 min or 5 min intervals)	Shows daily usage profiles allowing site and equipment usage patterns to be monitored and analysed. Can be used for invoice verification and reconciliation.
Real time	Data is available in real time, ideal for control applications such as load shedding, alarms, supply quality monitoring, etc.

There are three core elements to any system that we will now consider:

- Data collection
- Data analysis
- User interface

Data collection methods are outlined in Table 4.

Table 4: Data collection methods

DATA COLLECTION	DESCRIPTION
Hardcopy invoices	Received from utilities or your accounts payable group.
Electronic invoices	Received from utilities, (arrange as part of energy supply contract negotiations. Received from third-party service provider who obtains invoices from utilities or your accounts payable group
Utility smart meter data	Request from utility on monthly basis. Obtain from utility website or meter data agent.
Manual meter reading	Energy, facility management or maintenance staff (or third-party service provider) to manually read meters on monthly basis.
Automatic meter reading (AMR)	Pulse output, PC network, Powerline carrier, Wireless PC network, Radio, GSM, GPRS, SMS.

The data analysis capability of systems varies widely and for discussion purposes these have been categorised in to three broad levels described in Table 5.

Table 5: Data analysis categories

DATA ANALYSIS	DESCRIPTION AND EXAMPLES
Basic capability	Provides information in flat file and may provide basic graphing capabilities. May have alarm capabilities.
Good capability	Utilises data to provide high level summary information, reports, graphs and analysis.
Advanced capability	Incorporates tariff engines and can be expanded to provide full utility system functionality including billing.

Some common user interfaces are described in Table 6.

Building management and control systems (BMCS)

BMCS are commonly used to control air conditioning, lighting and other services in commercial buildings. They represent a considerable investment in infrastructure and can also be utilised for a wide range of monitoring functions. Modern BMCS are fully configurable, incorporate a web interface and are therefore appropriate for real-time monitoring, alarms and load shedding functions as well as general monitoring. Generally BMCS dating from before 2000 are less flexible and may not be appropriate for some monitoring functions.

Table 6: User interface types

USER INTERFACE	DESCRIPTION
Microsoft Excel	Do-it-yourself interface. Can incorporate macros for core processes.
Microsoft Access	Do-it-yourself interface that can accommodate larger quantities of data in Access database.
Free tools	Various free tools for managing energy data can be found on the internet. They have limited features and little flexibility but can be appriopriate for small organisations with minimal requirements.
Building management and control systems (BMCS)	Modern control systems have a wide range of features and are highly configurable. In new building design it is common to see 100 plus energy metering points connected to the BMCS. Can be a more expensive option as "control" quality hardware and systems utilised.
Specialist monitoring systems	A wide range of specialist systems are available. Many utilise specific data collection technologies and have limited features. Others can work with any data collection technology and have a high degree of flexibility.
Web interface	Third-party service providers usually offer web-based user interfaces, which have usability advantages. Some web interfaces can have limited flexibility. Web interfaces can be obtained for both BMCS and specialist monitoring systems.

BMCS are designed and built to manage devices in real time, and thus components are often higher quality and more costly when compared to specialist monitoring systems.

As a general-purpose control system, BMCS may also lack in-built advanced energy data processing and reporting functions, although these functions can be programmed into a modern BMCS. If a BMCS is already installed at a given site it should be considered as an option for implementation of a monitoring system and evaluated based on the overall objectives and costs.

Specialist monitoring systems

Specialist monitoring systems are designed specifically for monitoring purposes. Monitoring of utility data is not a critical application and a 100% success rate is not required. In practice, most field devices (eg meters) store data for weeks or months, so if a communication failure does occur the data can simply be collected at a later time.

This reduced reliability requirement often translates into more cost-effective solutions. Specialist monitoring systems can also incorporate tariff engines. The ability to store tariff information and calculate invoices can be used for:

- Tenant cost recovery
- Invoice verification (to reduce costs)
- Tariff analysis (to reduce costs)

Web interface

Systems with a web-based user interface or web option have a number of significant advantages including:

- Accessibility from any web-enabled PC at any time
- Accessibility for external companies or service providers
- Negates any requirement to install and maintain software on local PCs
- Software updates can be implemented on central web server and all users automatically benefit.

DESIGNING A MONITORING SYSTEM

This section presents a process for designing a monitoring system, and provides tools to assist with the design process. Note that the factors affecting monitoring system design are many and varied. This paper discusses only the key considerations.

Step 1: Objectives

Document your initial objectives, that is, the scope of monitoring and the features and benefits you wish to obtain from the monitoring system. Appendix A – Monitoring system design summary provides a convenient form for this purpose.

Step 2: Identify data source requirements

Cross-reference the benefits with recommended data sources in Appendix B – Matrix 1. Enter required data sources in the monitoring system design summary. Note that data from more than one source may be required to implement some benefits.

Step 3: Identify data resolution requirements

Cross-reference the benefits with recommended data resolution in Appendix B – Matrix 2. Enter data resolution requirements in monitoring system design summary.

In many cases a single data resolution will be sufficient. Some benefits may require data of different resolutions for comparison.

Step 4: Identify data collection requirements

Cross-reference the benefits with recommended data collection methods in Appendix B – Matrix 3. Enter data collection requirements in the monitoring system design summary.

In many cases a single data collection method will be sufficient. Multiple data collection methods may be required to achieve or improve some benefits.

Step 5: Identify existing infrastructure

There may already be significant infrastructure at your site that will assist or reduce monitoring systems costs. The following information should be obtained and incorporated into monitoring system design:

- Existing utility metering
- Existing sub-metering
- Existing communication infrastructure, eg computer networks or BMCS
- Existing possible user interface, eg BMCS

Step 6: Determine monitoring points

Selection of monitoring points is important for determining both the benefits that will be realised and project implementation costs. It is difficult to cover every possible scenario but some general guidelines for selection of monitoring points follow:

- Monitoring points should allow for an energy balance. For example, if all sub-meters are totaled, consumption should equal consumption recorded by a site – wide utility meter or appropriate master meter. Subtraction to calculate usage of any functional area, service or equipment should be avoided.
- A valid cost minimisation strategy is to commence monitoring at a high level. Once the initial system is implemented and data investigated, further monitoring can be targetted at those areas where greater understanding of usage patterns is required.

  Attempting to comprehensively monitor an entire portfolio or site from the outset can be an expensive project. If this approach is taken it is important to recognise that the monitoring system may require additional components in the future or will be implemented in several distinct phases.

If installing sub-metering throughout a single site or building:

- A good starting point for selection of sub-metering points is at switchboard level. i.e. consider installing a sub-meter on every switchboard and then adjust level of metering up or down as required. Building electrical drawings will assist.
- The existing electrical distribution and switchboard configuration needs to be taken into account, as it will often determine what can cost-effectively be monitored. For example, if office light and power circuits are mixed throughout distribution boards, metering lighting and general power separately may require expensive re-configuration of switchboards

Step 7: Determine communication methods (AMR only)

If sub-metering is required, it is desirable to implement automatic meter reading (AMR). Although AMR systems have been around for many years, technical advances have occurred in the past 10 years and both AMR implementation and communication costs have decreased.

There is now an ever-expanding range of metering and communications equipment available to facilitate AMR and the method of communication adopted will have a significant effect on overall implementation costs as well as ongoing communication costs.

The following table lists the most common methods of communication for AMR and describes the functionality in each case.

Step 8: Implementation and commissioning

It is essential during implementation and commissioning of a monitoring system that the following key information is recorded:

- Meter number /identifier for each meter
- Labels on each meter is clear and suitable for the local conditions
- Description of each meter location (marked drawings may be appropriate for some sites or facilities)

Table 7: AMR communication methods

COMMUNICATION METHOD	DESCRIPTION
Direct connection	Cable from meter to field control unit. Typical of BMCS installations.
PC network	Use PC network (cat 5 cable). May be more cost-effective to use existing network.
Power line carrier (PLC)	Meter sends signals over the electricity power cables to central reciever. Usually requires a secondary communication source to send information from central reciever to database.
Landline modem	Uses standard phone line and data modem to send information. Requires dailing that incurs call costs and associated reliability issues.
Wireless PC network	Use of wireless points on PC network to expand coverage without running cable.
Radio	Older technology used when running cables is not practical
GSM	Global solution for mobile communications (GSM) uses mobile phone networks and GSM modem to send data.
GPRS	General packet radio services (GPRS) is a mobile data service available to users of GSM. GPRS data transfer is typically charged per megabyte of transferred data, not connection time. It is therefore cost-effective for regular data transmission.
SMS	Uses integrated GSM modem to to send SMS, reducing hardware and communications costs. SMS can also be sent on lower strength network reception. Typically would send daily SMS with 48 x 30 minute readings for the day.

- Photo of each meter and surrounds
- Confirm meters are reading accurately and data is represented appropriately (eg in BMCS)
- The current transformer (CT) ratio for each electricity meter as applicable
- Gas pressure factors for conversion from m³ to MJ

Step 9: Ongoing management

Nominate a staff member to:

- Maintain the monitoring system
- Maintain monitoring system records
- Undertake regular analysis of monitoring system data.

SERVICE PROVIDERS

Designing and implementing a monitoring system is not for everyone. A wide range of service providers operate in the Australian market and offer a variety of monitoring systems that may meet your objectives. A specialist energy management consultant can be engaged to evaluate your requirements against available options and recommend a cost-effective solution utilising appropriate technology.

CASE STUDIES

The following section presents examples of implemented monitoring systems and benefits obtained.

Case Study 1 – Commercial facility

A simple manual process to monitor usage on utility invoices was implemented in a recently constructed facility. This immediately revealed that water consumption was excessive for the size and nature of the facility. Follow up investigation revealed:

- Broken system components
- Faulty and leaking toilet systems and control valves
- Broken irrigation system
- Vandalism, and
- Misuse of hose pipes (left running).

Correction of these issues restored water consumption to a reasonable level as per Figure 6. To ensure that utility usage remained at acceptable levels, automatic meter reading (AMR) systems were then installed via the BMCS.

Main drivers: Reduce environmental impact, manage utility costs

Scope: Single facility, 24-hour operation

Data types: Electricity, natural gas, water

Data types: Utility invoices

Data resolution: Monthly, quarterly

Data availability: Monthly, quarterly

Data collection: Utility invoices

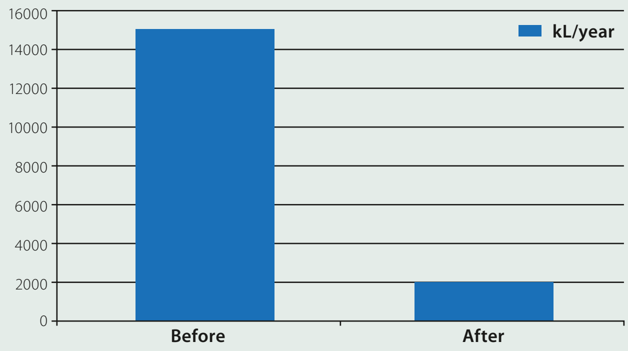

Figure 1: Before and after water consumption

Case Study 2 – Airport

Stage 1 of the monitoring system involved manual meter reading using a barcode scanner and PDA device. This monitoring was primarily for the purpose of invoicing tenants for energy use. Stage 2 (proposed) was to determine where energy was being utilised within the common areas and house services.

Main drivers: Invoicing tenants for usage (stage 1), manage environmental impact (proposed stage 2)

Scope: Multiple terminal airport incorporating domestic and international terminals

Data types: Electricity (400 metering points), natural gas (12 metering points) and water (40 metering point)

Data types: Utility meters, sub-metering

Data resolution: Monthly, quarterly

Data availability: Monthly

Data collection: Manual meter reading

Airport terminal

Case Study 3 – Government office building

Several suppliers of monitoring systems were invited to tender for sub-metering of a government office building. The successful tenderer provided a solution using powerline carrier technology for electricity sub-metering and GPRS for retrieving data from gas and water meters. The project allowed the breakdown of energy and water use within the building to be established leading to the development of targeted energy savings initiatives.

Main drivers: Manage environmental impact

Scope: Government office precinct

Data types: Electricity (70 metering points), natural gas (five metering points), water (one metering point).

Data types: Utility meters, Sub-metering

Data resolution: Quarter hourly

Data availability: Hourly

Data collection: Automatic meter reading

Case Study 4 – CBD office building

A monitoring system was installed to separate tenancy and base building energy consumption. A significant number of metering points were also installed to provide a breakdown of energy usage throughout the building. The metering system utilised standard phone lines to allow data for all meters to be retrieved from a central metering panel on a daily basis.

The monitoring system was used to identify energy saving opportunities and to evaluate the impacts post implementation. As can be seen in Figure 2, significant energy savings were achieved through an upgrade of lighting systems.

Main drivers: Manage utility costs, manage environmental impact

Scope: Single site

Data types: Electricity (50 metering points)

Data types: Sub-metering

Data resolution: Quarter hourly

Data availability: Daily

Data collection: Automatic meter reading

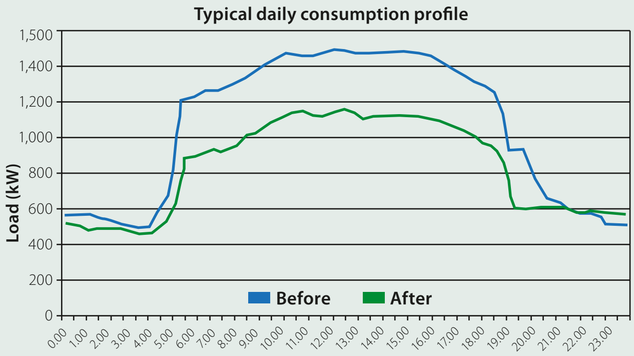

Figure 2: Typical daily tenancy energy usage profile before and after implementation of lighting project

Case Study 5 – Telecommunications company

A monitoring program was developed for a national property portfolio and has been continuing for several years. The monitoring forms a core element of a wider energy management program that seeks to meet legislative reporting requirements as well as reduce portfolio environmental impacts.

Information from the monitoring system was used to identify the worst-performing sites in each category and these have been targeted for energy efficiency initiatives. This simple approach has resulted in a significant reduction in energy consumption across the portfolio over a number of years.

Main drivers: Management of costs against budget, manage utility costs, manage environmental impacts

Scope: Property portfolio

Data types: Electricity, natural gas, floor area

Data types: Utility invoices, sub-metering

Data resolution: Monthly, quarterly, bi-annual, annual

Data availability: Monthly

Data collection: Hardcopy invoices, electronic invoices, automatic meter reading

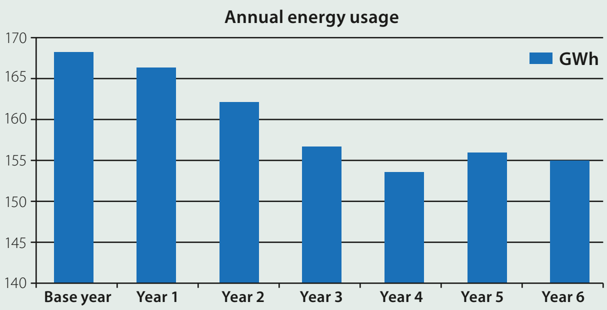

Figure 3: Portfolio energy usage

GLOSSARY

Term	Definition
Invoice validation	Validation of consumption and costs by comparison with previous invoice, same invoice last year, etc
Invoice verification	Recalculating invoice costs from raw meter readings and published tariff information/ contracts to verify utility invoices
Invoice reconciliation	Recalculating utility meter readings from 15 or 30 minute meter interval data
Tariff analysis	Analysis of tariff options to identify less expensive alternatives
TBL	Triple bottom line
EDGAR	Environmental data gathering and reporting
OSCAR	Online system for challenge activity reporting
Greenhouse Challenge Plus	Australian Greenhouse Office voluntary program to encourage companies to reduce greenhouse gas emissions
DEUS	NSW Department of Energy, Utilities a nd Sustainability
EEO	Energy efficiency opportunities
LPG	Liquefied petroleum gas
EPA	Environmental Protection Agency
GHG	Greenhouse gas
ABGR	Australian building greenhouse rating
NABERS	National Australian Built Environment Rating System
Pseudo real time	Close to but not actually real time
GSM	Global solution for mobile communications
GPRS	General Packet Radio Services
CT	Current transformer
PLC	Power line carrier
AMR	Automatic meter reading
BMCS	Building management and control system
kWh	Kilowatt hours
MJ	Megajoules
m^2	Square meters
m^3	Cubic meters
APPENDIX A	Monitoring system design summary Please visit www.airah.org.au to download Appendix A.
APPENDIX B	Matrix 1 to 3 Please visit www.airah.org.au to download Appendix B.