Australian Government
Department of Industry

CASE STUDY

ENERGY EFFICIENCY AT THE **UNIVERSITY OF QUEENSLAND**

The University of Queensland (UQ) is building a culture of sustainability and energy efficiency across all campuses. This case study describes UQ's energy efficiency program at St Lucia Campus, where centralised energy management is providing UQ with a better understanding of its energy use. UQ has developed user-friendly online graphical user interfaces for staff and students of varying expertise to interact with energy data. This greatly assists identification of opportunities and promotes energy efficient behaviour.

Energy efficiency is one of the strategies being pursued to achieve UQ's aspirational carbon reduction pathways. Reductions are expected to be achieved through a combination of energy efficiency, behavioural change and renewable energy.

The energy efficiency component has been influenced in part by the Australian Government's Energy Efficiency Opportunities (EEO) Program, which UQ joined in 2010. The EEO Program requires participants to identify and evaluate opportunities to improve their energy efficiency and productivity.

Implementing energy efficiency measures and a carbon reduction pathway helped build the business case to establish UQ's Energy Management Office (EMO). There was also strong interest at UQ in linking energy and carbon programs to teaching and research, and building a culture of sustainability and energy efficiency across all campuses.

Since 2010, the EMO has established systems for financial management of energy and has rolled out an extensive metering system. More comprehensive data on energy use helps to determine where opportunities for improvement exist.

Energy Efficiency Opportunities

ENERGY USE AT ST LUCIA

The St Lucia Campus consumed around 431,000 GJ of energy in 2011–12. The energy was comprised of electricity (94%), natural gas (1.3%), solar power (1.4%) and LPG, gasoline, diesel, ethanol and petrol-based oils (3.3%).

The campus includes 37 large buildings and approximately 100 buildings in total, spread out over a 114 hectare site. These range from cafeterias to state-of-the-art biological research facilities, which have very stringent air-conditioning and air-flow requirements. The campus size and varied facility requirements make reducing energy consumption on campus extremely challenging.

University facilities staff manage a range of specialised building types. In addition to looking after office spaces, they also manage engineering laboratories, veterinary research facilities and data centres, among others. Many of these buildings have complex operational requirements; for example, chemistry laboratories contain multiple fume hoods, which present air-conditioning challenges, and microbiology laboratories have pathogens which must be contained.

The EMO, which sits within the Property and Facilities (P&F) division, has to operate within a constrained budget. In the commercial sector, an expensive energy-efficiency re-fit can justify higher rents.

Green buildings with high NABERS (National Australian Built Environment Rating System) ratings command a premium in the commercial sector, but this kind of financial benefit is unlikely to be seen within a university.

Another challenge is that energy consumption has been increasing at UQ, primarily due to the growth in gross floor area. Other factors contributing to higher consumption include:

- an increase in student numbers
- longer operating hours and greater demand for 24-hour access
- increased demand for air conditioning
- more computers and electronic equipment
- increased research activities, which are more energy-intensive than offices and teaching facilities.

The University of Queensland

UQ is one of Australia's largest universities with around 46,000 students and 7,000 staff members.

The university's main campus at St Lucia is set on a 114-hectare site bounded by the Brisbane River, seven kilometres from the Brisbane CBD. In 2013, it supported around 32,000 students and 5,000 staff members.

Business opportunities

- Centralisation of energy cost management to the Energy Management Office enabled $1.45 million in savings to be identified in 2012 (e.g. from double billing and incorrect tariffs) and $44,500 to date in 2013.
- UQ analysed the performance of air-conditioning chillers, which consume an estimated 45% of the energy on campus. The university is planning to install an optimisation package on the chillers that would ensure that they run as efficiently as possible. This is expected to:
  - – reduce energy consumption by around 20%
  - – save more than $100 000 per year
  - – enable a payback of less than two years.

IMPROVING ENERGY MANAGEMENT

The changes being implemented at UQ in 2013 are discussed below under the six requirements of the EEO Program:

- leadership
- people
- information, data and analysis
- opportunity identification and evaluation
- decision-making
- communicating outcomes.

Leadership

Energy efficiency is a key component of the sustainability program at UQ, which aims to embed sustainability in operations, teaching and research activities across all campuses. The sustainability policy outlines high-level commitments including resourcing and accountabilities. The environmental management system includes an energy management program, with actions and responsibilities.

In 2010, the then vice-chancellor endorsed an aspirational carbon-reduction pathway. This is expected to be achieved through a combination of energy efficiency measures and additional on-campus renewable energy systems.

The EEO Program, combined with the university's strong commitment to sustainability and carbon-reduction, led to the establishment of the Energy Management Office (EMO) within the Properties and Facilities (P&F) division in 2010. The EMO's role includes energy procurement, infrastructure development and maintenance.

Formal relationships were established between the EMO and key university groups. This included P&F's Engineering Services, the Renewable Energy Project Control Group and the Infrastructure Sub-committee.

Figure 1 shows where the EMO fits in the organisational structure at UQ. Energy management was introduced as a standing item for meeting of the Sustainability Steering Committee.

The new governance structure has significantly improved the way energy is managed. Previously, the university lacked a formal decision-making process linking to the energy budget and there was no connection between energy programs and senior management.

Changes were made to financial management to improve transparency and incentives for energy efficiency. Under the pre-existing arrangement, the budget was split between the Finance division (energy purchase) and the P&F division (energy efficiency and renewable power). This disconnect meant that P&F did not understand consumption across the campus sufficiently to develop effective reduction plans. Consolidating the entire energy budget into the EMO allowed them to divert any savings from energy procurement into energy efficiency and related projects.

After the EMO became responsible for paying the bills, accounts were checked for accuracy. Identification of errors led to the reversal of $1.45 million of charges in 2012 and around $44,500 to date in 2013. These errors included incorrect network and energy tariffs, as well as double-billing for some of the university's major sites. The savings from identifying these errors were channelled into energy efficiency measures through the operational budget—this is in addition to an annual budget of around $600,000–800,000 for metering, software, audits and other projects.

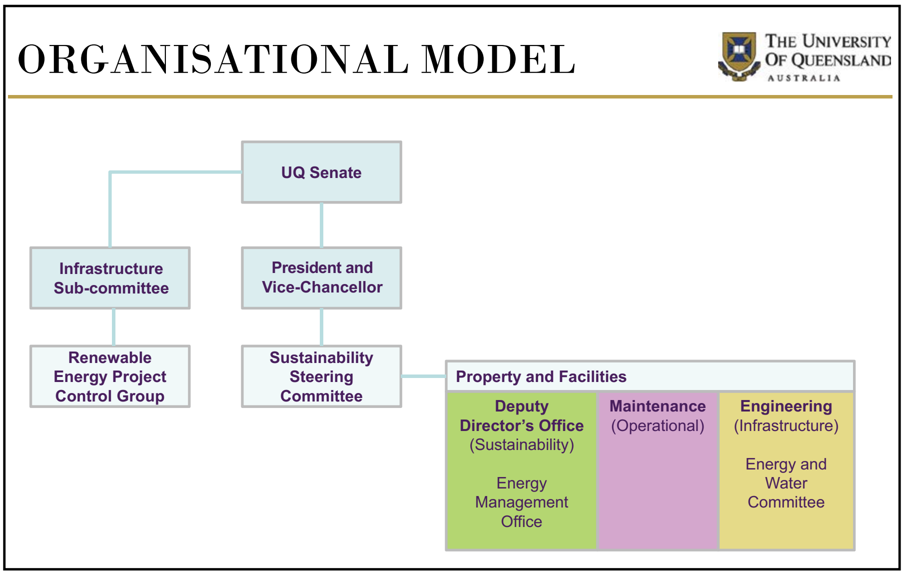


Figure 1: Organisational structure of UQ.

People

To run the EMO, an energy manager with university experience was recruited along with staff to meet the growing workload as projects were implemented. As of 1 July 2013, the team included five full-time equivalent staff with skills in energy accounting, data collection and analysis.

The EMO developed a comprehensive program aimed to create a culture of energy efficiency at UQ. It is recognised that it is not enough to simply build or retrofit a green building—the building needs to be operated in alignment with the design intent, or expensive technologies and systems will be rendered ineffective. The Sustainability Steering Committee has improved communication at the management level, and a range of data collection and communication projects is being implemented to guide more informed choices among staff and students. Some of these are presented below.

Information, data and analysis

Project to map and improve metering

It became clear to the EMO team that a more extensive metering system was needed to determine where and how energy was consumed.

A major review was undertaken in 2011–12 to map the location of existing meters and document what they were measuring to identify any gaps in the system. A decision was then made to install meters on all of the major buildings on campus as well as on chiller motors, pumps and cooling towers. The meter installation will be completed in 2013 and all meters will be integrated into energy management software by the end of 2014.

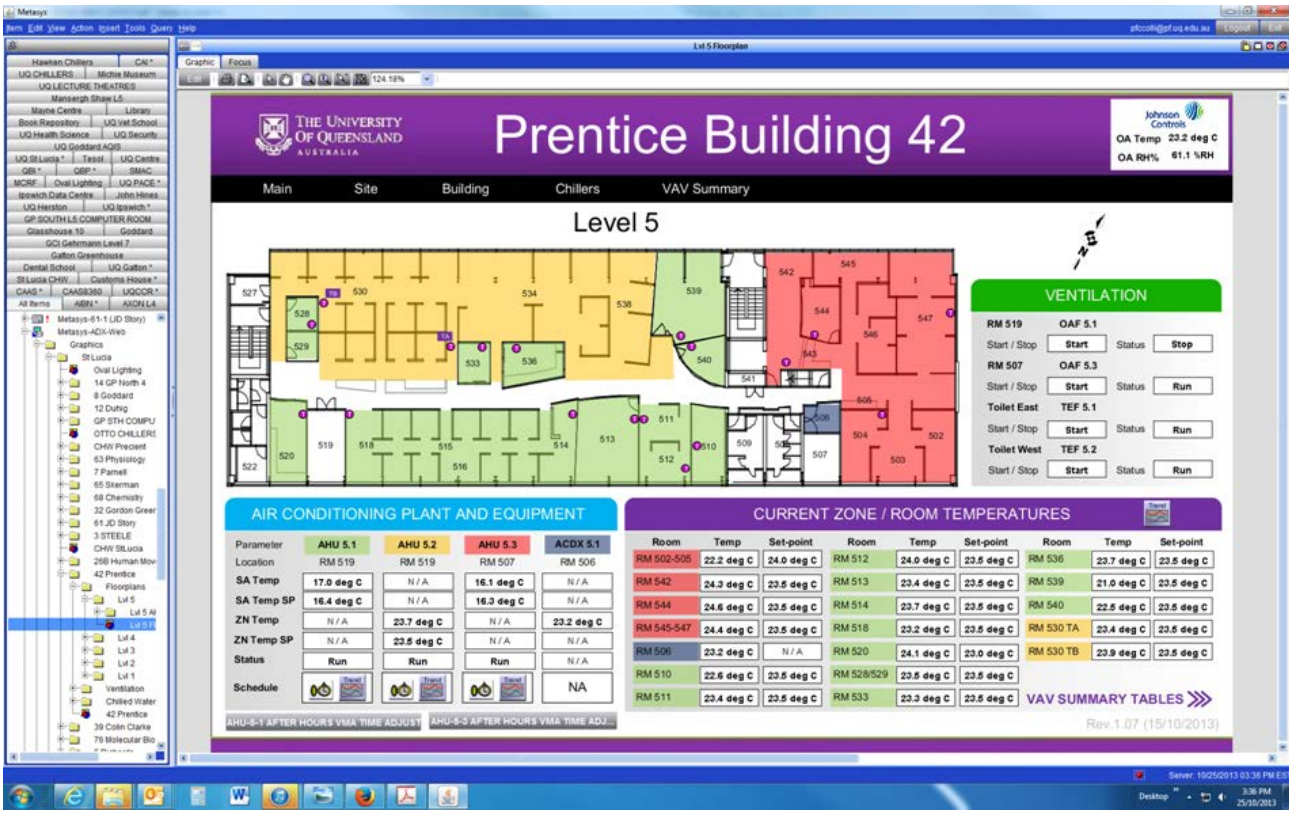
The business case for the metering project was based on:

- the expectation that meters would help to identify energy saving opportunities
- the requirement to install sub-metering on new buildings to achieve Green Star[1] certification.

More information is provided in 'Lessons learned' (*Building the business case for meter installation*, p. 9.

While the installation of meters is underway, various methods are being explored for the collection and presentation of the data to inform best practice.

1 Green Star is a comprehensive, national, voluntary environmental rating system that evaluates the environmental design and construction of buildings and communities



The data will be analysed at a technical level by EMO staff and facility managers, and used in a simplified form by building occupants, academics and students.

Designing a more user-friendly building management system

The university has a building management system (BMS) that controls air conditioning and lighting. It can be programmed to reduce the amount of energy consumed, by scheduling and minimising run times.

Accessing BMS data involves navigating a complex file structure. A new graphical user interface is being developed that shows the equipment which serves individual rooms and provides quick links to data. For example, **Figure 2** shows a prototype for how air-conditioning information would be portrayed graphically on desktops. The new approach is part of a suite of user-friendly tools that will greatly improve visibility of the BMS and enable users to identify delinquent performance, and aberrant scheduling. This will allow for improvements to service delivery and energy efficiency.

The type of BMS installed at the university has limitations when used as an energy monitoring system. It has some capability for recording energy use, particularly the electricity consumption of chillers, pumps and fans. However, the recorded data can be difficult to access, and when needed for auditing purposes, assistance from the system installer is often required. The BMS also has limited ability to store information, so it is not possible to review trends over several years.

Installing a state-of-the-art energy management system

Until recently, the university had a rudimentary electrical meter recording system that stored data as text files and used MS Excel to run reports and produce trends. Only specially trained EMO staff and students could access the data. To address these limitations, the university trialled a separate supervisory control and data acquisition (SCADA) system for the central chiller station in 2012, before rolling it out to other buildings from 2013.

The new energy management system is more user-friendly because it allows effective long-term data storage, easy retrieval of data, and enables relatively inexperienced operators to produce reports. This means more people, especially students, can take part in the energy management process of identifying opportunities for improvement.

An example of the information displayed by the SCADA system is provided in **Figure 3**. This shows the layout of thermal meters and electrical meters on three chillers, and has been designed to the university's requirements. Once the precinct is selected, the user can click on a button to view a report on chiller performance (measured as the coefficient of performance [COP] which is explained below in *Opportunity identification and evaluation – improving chiller efficiency (p. 7)*.

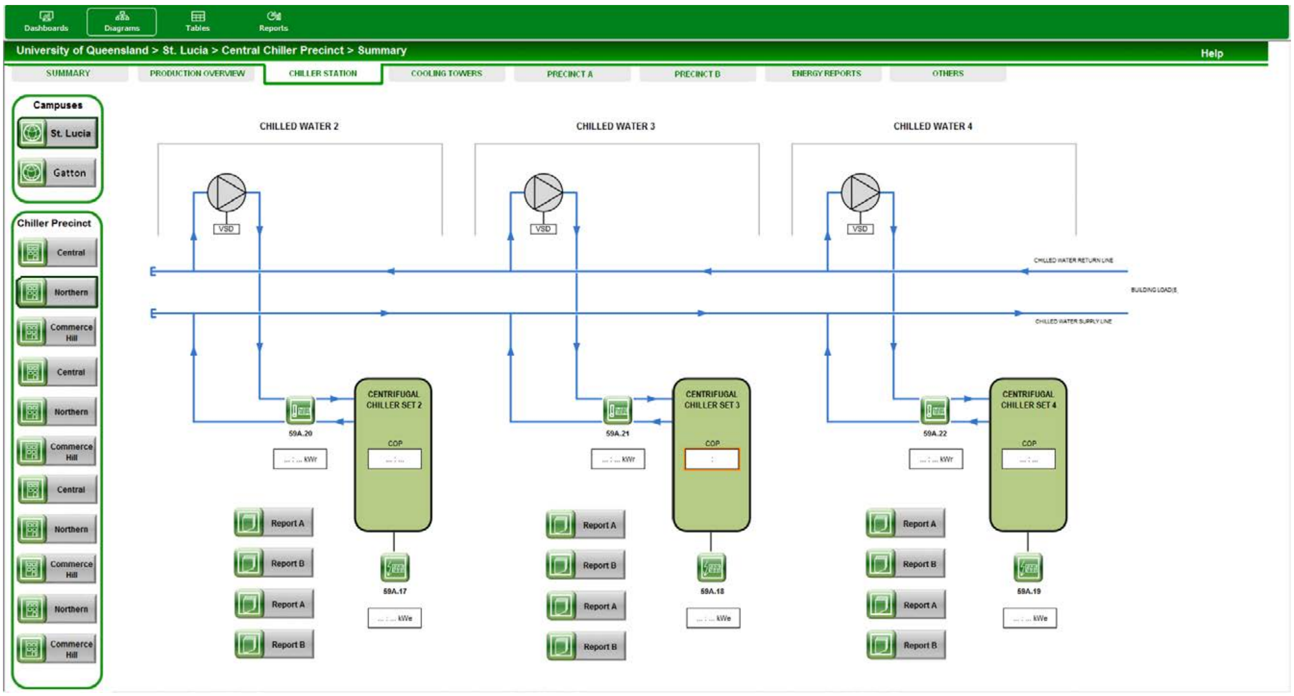


Figure 3: SCADA System - Metering schematic for three chillers showing electrical and thermal metering.

Using data more effectively for monitoring and communication

The SCADA system makes it easier for a variety of end-users to access the data from the BMS, and will be used to optimise performance and identify opportunities. However, it does not have the level of interactivity that people have become accustomed to on websites and via social media. It has limitations in terms of facilitating communication and engagement with building occupants and other target groups. To meet this need, the EMO has developed its own one-page graphical user interface to display data from the meters. This will:

- inform building users (staff and students) about energy use via websites and LCD screens in building foyers, and to encourage energy-efficiency practices
- enable energy managers to monitor real-time data in order to analyse trends and identify when a system is showing delinquent behaviour
- allow energy managers to benchmark the buildings against industry norms and best practice
- support teaching and research activities in sustainability and energy management.

Figure 4 shows an interactive screen that focuses on the photovoltaic (solar panel) energy system. A touch screen allows the user to choose the site, the type of data and the time period that they are interested in. The screen then shows total energy generated by the system, trends over time, financial savings, and greenhouse gas reductions achieved.

It can be accessed by users on any desktop computer (http://uqld.smartersoft.com.au/user/reportEnergy.php). The desktop version has a facility that enables students and staff to download data for use in teaching and research, further adding to the engagement value of the display. A touchscreen version is being trialled on an interactive LCD display in the foyer of the Prentice Building. Properties and Facilities recognise that energy information may be fairly dry to some viewers. For this reason, touchscreens will also provide other information that may be more likely to draw people in, such as current weather reports.

While the interface currently only shows the photovoltaic system, a live building energy display will soon be added. This will have the same visitor view options, as well as other screens for higher level interactivity.

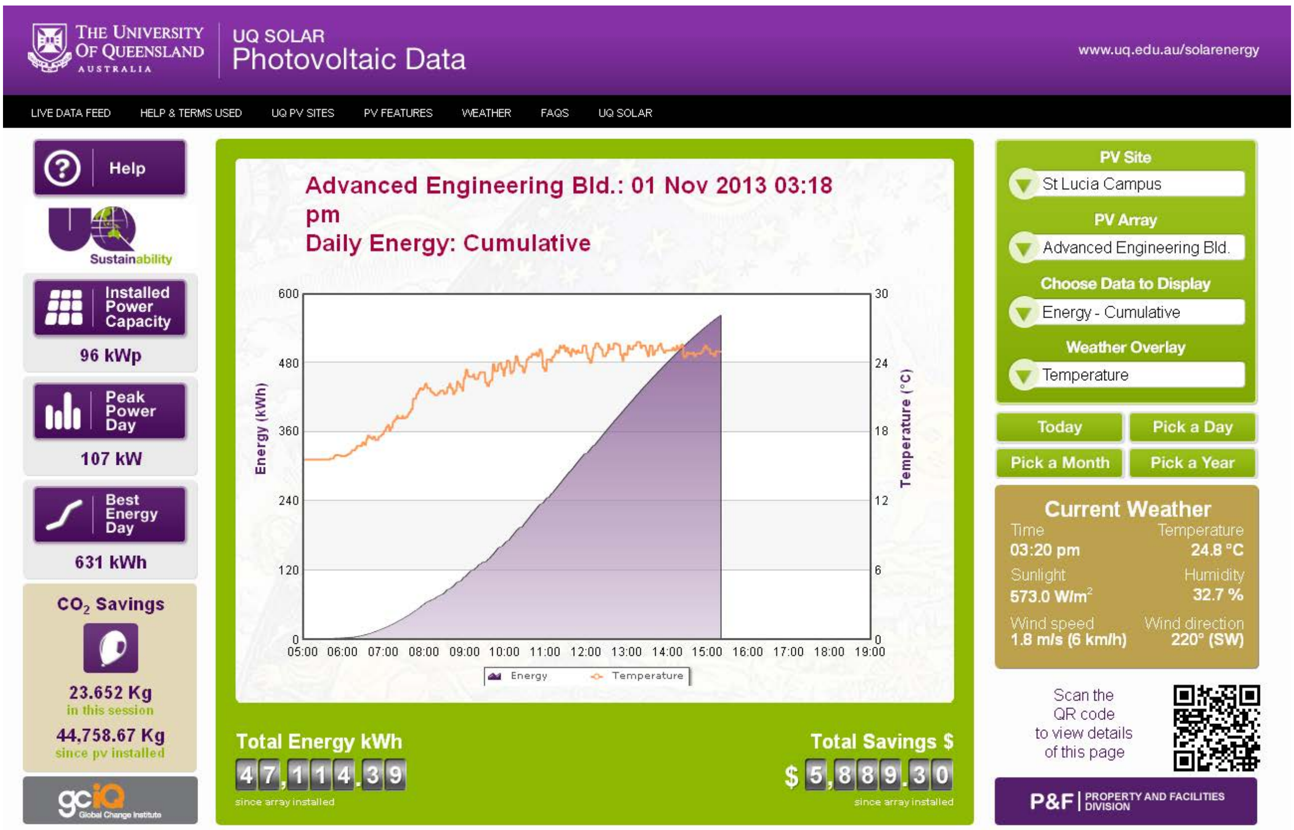


Figure 4: Interface for the photovoltaic data.

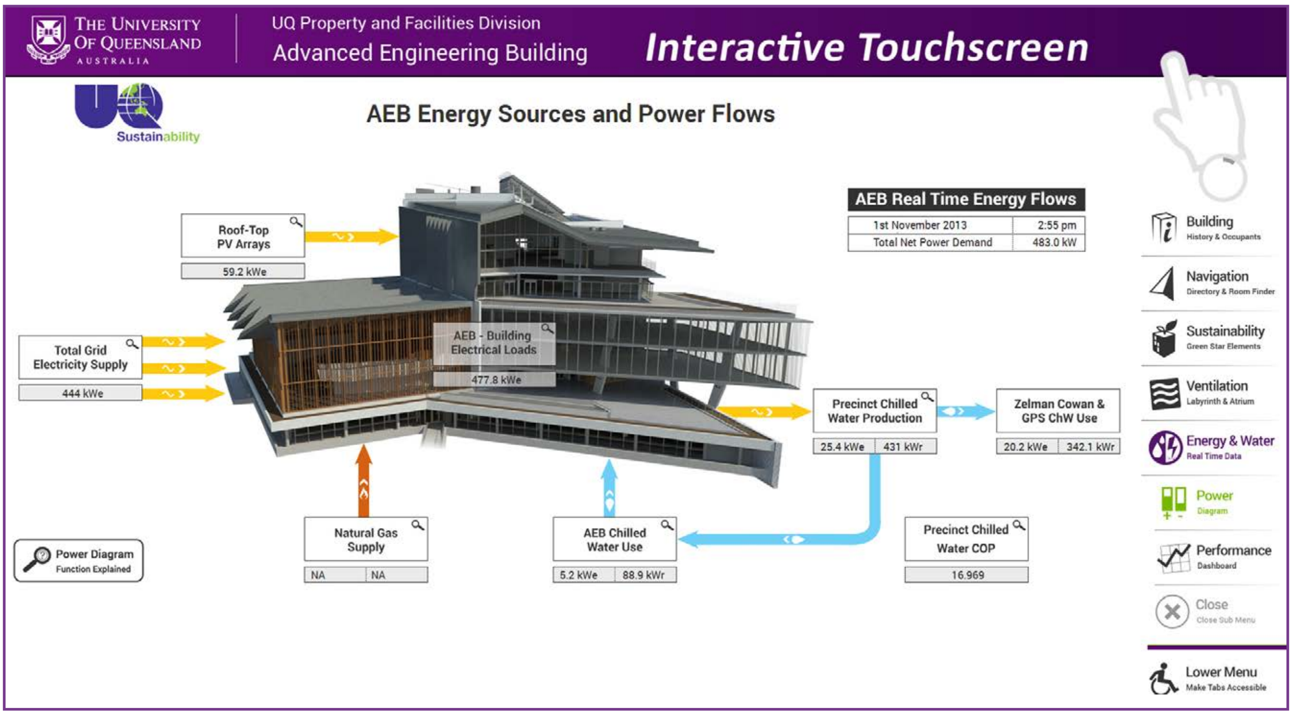


Figure 5: Interactive touchscreen showing real-time energy flows.

Other energy displays such as consumption dashboards and real time energy flow diagrams are also under development. An example of the latter is presented in Figure 5.

Opportunity identification and evaluation

The EMO engaged consultants to analyse the new metering data and to identify energy-saving opportunities. As a result, lighting retrofits were carried out in eight of the largest buildings on the St Lucia Campus and solar film was applied to reduce heat gain through glazing.

The EMO also analysed metering data from the chiller motors, pumps and cooling towers and identified an ambitious opportunity to optimise their performance. This project is described below.

Improving chiller efficiency

Air conditioning is the largest consumer of energy at UQ. The service is mostly provided by chilled water produced in central chiller stations supplying a number of buildings (the largest chiller station services 13 buildings). Grouping chillers in this way allows them to be situated in easily-accessible locations. The number of individual machines can be reduced, and there are other economies of scale compared to installation in individual buildings.

One audit suggested that these central cooling plants might use up to 45% of all the electricity consumed on campus. Staff members are working to reliably confirm this estimate using the latest measurements. Given the high energy use, there is a large potential benefit from improving the efficiency of operation.

The installation of electricity and thermal meters on each chiller allowed the energy team to measure the COP (coefficient of performance) for each chiller. The COP could then be displayed on the SCADA system. The COP is the ratio of the cooling energy provided, to the electrical energy consumed. By measuring the chilled water flow and the temperatures of the flow and return water, the cooling effect can be gauged. The COP is similar to an efficiency indicator, but because a chiller is a heat pump the value is larger than 1. An older style chiller might achieve a COP of 3.5 while modern chillers operating under ideal conditions can attain a COP of 12 or above.

Figure 6 displays the metering reticulation, and Figure 7 shows the type of analysis that can be undertaken using the metering data. The graph shows the efficiency of a chiller during relatively low load conditions. It indicates that for 50% of the time, the chiller performs above a COP of 3, but only 20% of the time above COP 3.5. This level of performance falls well short of expectations, and the chiller project aims to improve this.

The EMO evaluated a number of options to improve efficiency. One option was to replace the aging chillers,

but this was considered to be overly challenging and expensive. Two options that were deemed relatively easy to implement were chiller staging and control of condenser water temperature. These options only depend on changes to control and do not require any plant upgrade. The P&F division is installing an optimisation package (hardware and software) that will run the chillers as efficiently as possible in relation to these two parameters.

To further optimise the efficiency of the chillers, they can be run during the cooler part of the day when the COP is optimal . To ensure the supply of cold water is continuous, thermal energy storage (TES) would be installed. This would effectively decouple the building load from the chiller which would be run at maximum COP. The university is exploring large-scale TES at its Gatton Campus.

In the meanwhile, the university is installing a smaller TES, a 40,000 L chilled water tank, as part of an upgrade to the cooling system in the Otto Hirschfeld Building. This is to deal with the type of low-load problem illustrated in Figure 7. At low load, the chillers run inefficiently. By linking the chillers to a TES, they can be cycled on and off, and when operating they can run at higher loads and better efficiencies.

There is potential to adopt this solution for many of the chiller precincts, but there are physical constraints in some areas such as lack of space and incompatibility with heritage buildings.

As an alternative to TES at the St Lucia Campus, the university is looking to improve low-load performance by installing suitably sized low-load chillers that can efficiently provide the cold water levels needed in winter. Over time the university will also replace its larger chillers with modern equipment that runs more efficiently at low loads.

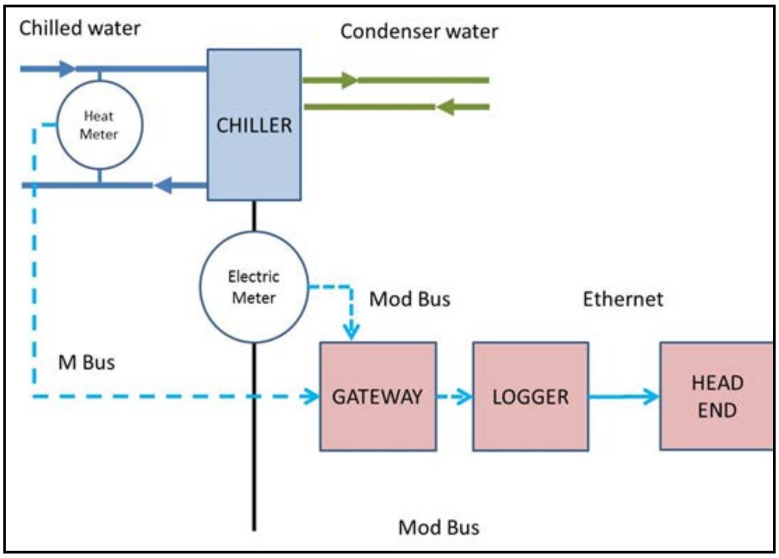


Figure 6: Metering reticulation.

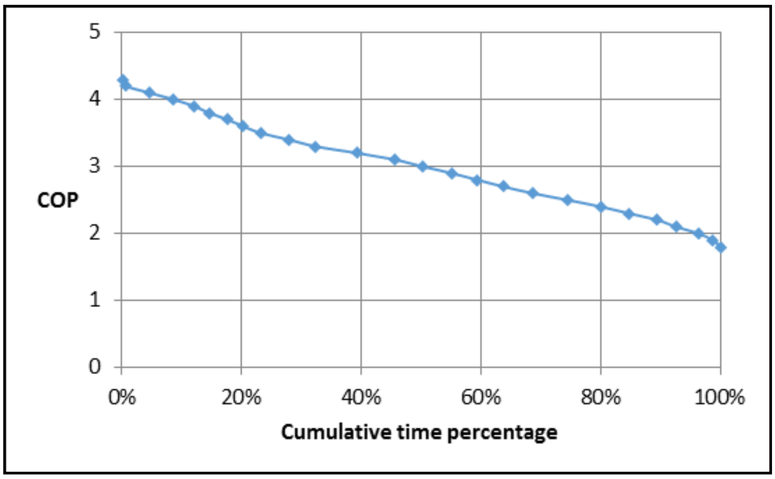


Figure 7: Chiller cumulative performance.

Inside a chiller room.

For higher loads, the university is looking to install more of the optimisation packages mentioned above.

Decision-making

The EMO has found it difficult to develop a business case for energy efficiency projects at the St Lucia Campus because that campus can access relatively low-cost electricity. Another factor is that energy consumption rarely goes down as a result of an energy efficiency project. This is partly because new and refurbished buildings have air conditioning and additional equipment which the original buildings did not.

To help with the business case, P&F forecast energy projects mid-project, and use average rather than marginal costs because these are higher. The long-term reduction in operating costs is taken into account and, wherever possible, projects are also linked to other benefits such as:

- their contribution to the aspirational carbon reduction pathways
- teaching, research or community engagement activities.

Communication

The EMO works closely with the university's Office of Marketing and Communications (which is represented on the Sustainability Steering Committee), to promote energy efficiency initiatives and positive behaviour. These are achieved through a number of strategies, including:

- reporting energy use and energy-saving projects through interactive foyer displays
- the Green Offices and Green Labs programs, which are run by student and staff 'champions'
- the sustainability newsletter and website, which feature energy saving tips.

Communicating energy efficiency to staff and students can be challenging because it is not always seen by building users as a priority. The EMO tries to design spaces and education programs that are consistent with their work requirements; for example, the Green Labs program provides specific advice on the energy efficient operation of fume hoods and other laboratory equipment.

'Research staff are highly focused on their own work. You have to understand their underlying needs and try to find ways that this can be carried out in an energy efficient way.' Chris Collins, UQ Energy Manager

The EMO is also working with research institutes that have a strong focus on sustainability, such as the Global Change Institute.

The EMO intends to present faculties with data on their energy use, showing how that usage has changed over time. Opportunities to reduce consumption will also be highlighted. Data analysis will support behaviour change with the provision of energy information and advice, rather than through direct recovery of energy costs. Data will be used, for example, to show the high costs of air conditioning and the benefits of adapting to ambient temperatures.

Lessons learned

Building the business case for meter installation

Without metering it is almost impossible to reveal opportunities and make a case for improvement. However, it can be difficult to determine and communicate the benefits a metering system will deliver when there are no meters in place to start with. UQ initially approached this problem through a combination of temporary trial metering, the application of experience and development of informal guidelines.

Projected financial benefits of the central chiller project, for example, could not be ascertained without knowing how much electricity was being used by the existing chillers. The minimum energy cost was estimated to be $350,000 per annum, but was suspected of being considerably higher. Temporary metering, at a cost of around $5,000, was installed to gauge thermal output and electrical input. This exercise indicated that the system was operating at low COP and that annual electricity costs could be closer to $500,000 per annum.

The cost of installing a comprehensive metering system was estimated to be $50,000 and the cost of the optimisation package at around $100,000. If electricity costs were, in fact, $500,000 per annum and a very conservative 10% saving ($50,000) could be achieved, then the project (at a total cost of $150,000) would have a three-year payback.

Permanent metering was installed and integrated in 2012. The new system showed that annual electricity costs were even slightly more than $500,000 per annum, and a contract was signed for the installation of the optimisation package. The payback for the whole project—the optimisation package and the metering—is now expected to be less than two years.

Projects such as this have enabled UQ to develop informal guidelines to inform the business case for

metering. As a general rule of thumb, a single meter at UQ might pay for itself by helping to identify just one project if the load it monitors exceeds around 100,000–200,000 kWh per annum. This range allows for different assessments of the likely benefits of energy efficiency opportunities that metering can reveal.

Making effective use of energy data

UQ is following a process to collect more accurate data on energy use and then convert this data into useful information for decision making (**Figure 8**).

Electricity and thermal meters will provide the data that is essential to understanding energy consumption across the campus and for identifying opportunities for improvement. After meters were installed on each chiller, this data was used to analyse their performance. An opportunity was identified to optimise the operation of the chillers without the need for significant investment in a new plant and equipment.

The EMO is also continuing to implement changes to the way data is presented so that it can be used more effectively to identify opportunities.

The need for strong executive support

Investments in energy efficiency require leadership at a senior level. Commitments need to be formalised in the organisation's vision, and policies approved by senior management. The P&F division believe they have partially achieved this through integration of the Sustainability Program, Sustainability Action Plan and EMS, but energy efficiency still has a tendency to be 'designed out' of major projects due to budget constraints. This is being addressed through improved design guidelines (see *Next steps*, p. 11).

Using consultants more effectively

Consultants are often used to undertake energy efficiency audits, but the quality of their work is not always project ready; that is, it can't be directly translated into a scope of works. Consultants' advice on lighting retrofits, for example, had to be thoroughly reviewed because some recommendations were not specific enough and in some cases not entirely practical. P&F now asks consultants to complete an Excel spread sheet to create a report that clearly specifies the work so that it can be handed to an appropriate contractor for implementation. Opportunities are being explored to engage students in surveys that underpin the lighting retrofit report, for example, by recording lux levels needed to detect over-lamping (a common problem in corridors).

Changing perceptions of building comfort

The energy efficiency of buildings relies as much on user behaviour as it does on design and technology.

'We've had success in designing buildings with potential, for example with natural ventilation. The challenge is that people complain that they are too hot, and it's tempting for the building manager to close the louvers and switch over to air conditioning mode.

'We need to educate people that the outside air is 25 degrees and it's OK, which is why the louvres are open. To get the message across, we'll use the touch screens in building foyers. We're trying to change people's expectations in line with the building's potential.'

Chris Collins, UQ Energy Manager

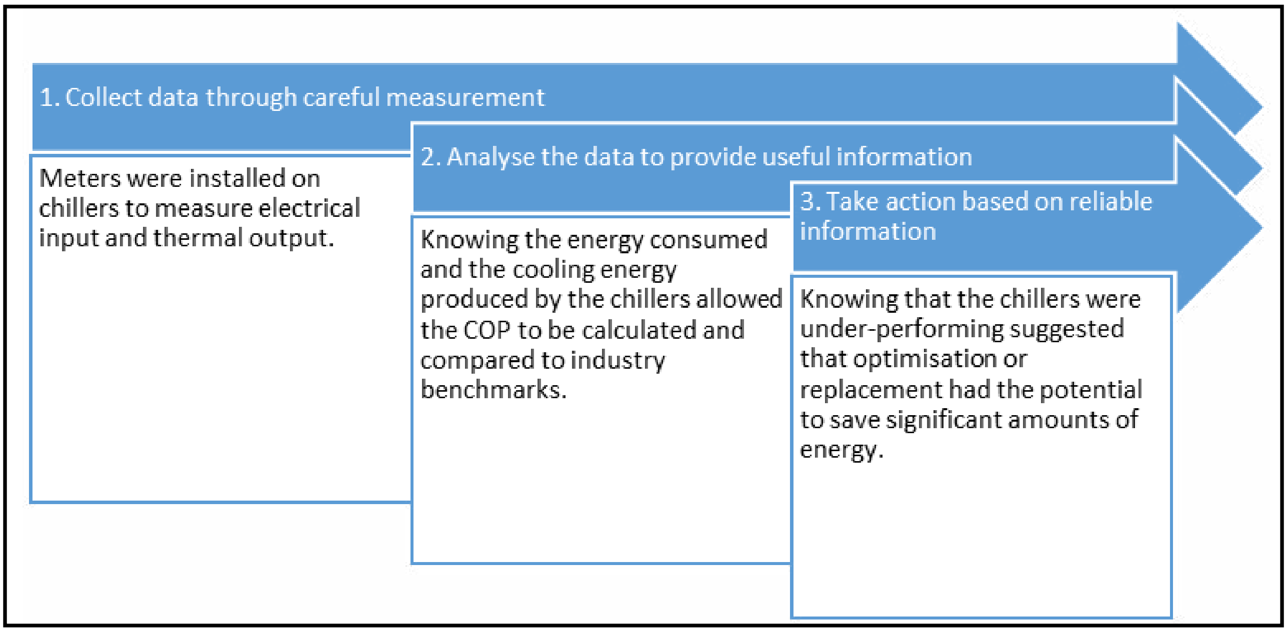


Figure 8: Process for more effective use of energy data (chiller example)

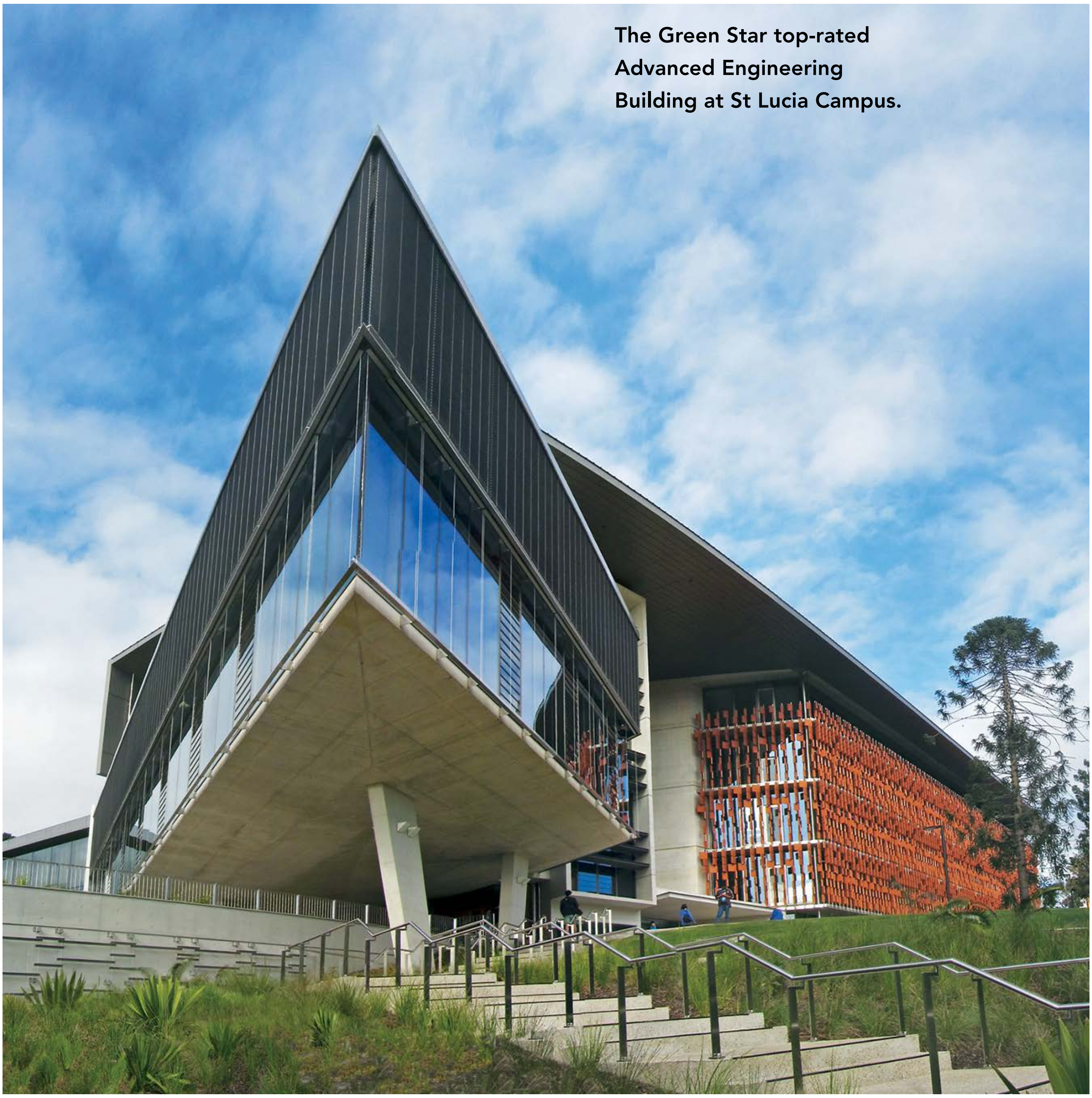
The large and changing population of students that use the St Lucia Campus every day presents a significant challenge for ongoing communications and engagement activities. For example, academic staff members and graduate students tend to be risk-averse when it comes to modifying behaviour that might impact on their research activities.

The EMO has responded to these challenges by developing a diverse communications and engagement program that considers the particular needs of each target group, including the general student population, office staff, laboratory users and college residents.

The university's core focus on research and teaching provides an opportunity to build on internal knowledge and expertise. Research groups such as the Global Change Institute are being utilised as champions to promote energy efficiency and sustainability programs. Academics and students in a range of disciplines, from economics to engineering, are invited to contribute to research that supports the work of the EMO.

Next steps

UQ has an ambitious strategy to improve energy efficiency across the university. Initiatives underway at St Lucia will be used to improve the operation of existing facilities and to inform the design of future building and renovation projects.



The Green Star top-rated Advanced Engineering Building at St Lucia Campus.

Property & Facilities Division | The University of Queensland

Continuing the roll-out of meters

Electricity meters have been installed at output points for all of the 37 main buildings on the campus, but only three have thermal meters. The priority is to install meters on the chillers and to link these to the optimisation package. The complete roll-out of thermal meters is expected to take several years.

Design guidelines

The energy management team already has input to building design and construction projects on campus, such as the new Advanced Engineering Building (Figure 9). However, all possible energy efficiency design options are not always implemented for budget reasons, or because there is a lack of effective communication between contractors.

To address this challenge, P&F is undertaking a full review of their design and construction guidelines to ensure that energy efficiency is a high priority and properly implemented.

There is a trend within universities is to operate around the clock rather than at fixed times during the day and evening. Architects need to understand work practices and ensure that air conditioning can be targeted to particular spaces and only when people are using them. Plant rooms also need to be designed to be large enough to work efficiently. Efficient air conditioning therefore requires effective communication between the architects and the mechanical engineers early in the design process.

A design and construction advisory note is being sent to all UQ architects, mechanical engineers and contractors. The advisory highlights recent shortcomings in air conditioning user briefs, design, construction and commissioning. It suggests changes to ensure that the university gets better value for money, improved service delivery and greater energy efficiency.

Focus on other campuses

St Lucia Campus consumes around 75% of the university's annual energy budget, with the remainder consumed at Gatton, Herston, Ipswich and a number of smaller sites. While it made sense to initially focus on the main campus, the other sites pay a higher energy tariff and as a result may have a stronger business case for energy efficiency. In future there will be a greater focus on each of these campuses.

Renewable energy demonstration project

A major project currently being developed is to install a range of renewable energy technologies at the Gatton Campus. This will become a demonstration site for new and innovative technologies utilising solar, geothermal, and biomass energy resources. Energy efficiency will also be an integral part of the design.

Conclusion

The EEO Program requires the use of appropriate energy data collection, measurement and analytical techniques. This case study demonstrates some of the strategies that can be implemented to achieve this within the commercial and institutional property sector. Energy use data is essential, but it needs to be converted into useful information. At UQ changes to the graphical user interface for the BMS and a new SCADA system to improve usability will allow managers to track performance in real time and fix problems as they arise.

UQ is also trialling the use of desktop and foyer displays that can support behaviour-change programs. Green buildings and technologies are only effective if used appropriately. Timely data on energy use, when presented in an attractive and engaging format, can allow building users to make more informed choices.