Feat of engineering

As the first of three facilities to be delivered under a $1 billion masterplan, the new Faculty of Engineering and IT (FEIT) building at the University of Technology, Sydney embodies the future focus of its occupants, reports regular Ecolibrium correspondent **Sean McGowan**.

No doubt you'd heard the term "living laboratory", particularly as it applies to the tertiary education sector. It refers to buildings that are designed to reach beyond their traditional functions of merely hosting classes, to substantially enhance the student learning experience.

It also implies the building itself is a teaching aid, and that the technologies it employs and how it performs can offer valuable lesson for those who pass through its doors.

The new Faculty of Engineering and IT (FEIT) building at the University of Technology, Sydney (UTS), however, has taken the concept considerably further than most.

Indeed, such was the commitment of the university to its students' learning experience that many of the building's design features would never have been included if cost and building expediency were the only considerations.

Included among the exotic kit used in the building are a hydrogen fuel cell, organic rankine cycle (ORC) turbine, solar-thermal cogeneration system, as well as roof-mounted solar PV array, solar-thermal parabolic trough collectors, and a vertical-axis wind turbine.

> "It is the opinion of many that the building was designed using a 'form before functionality' approach"

BEST FIT

Following planning approval in January 2010, Waterman was appointed to provide mechanical, BMCS, electrical and ESD engineering on the project.

Main contractor Lend Lease was then brought in part way through the design process to provide early contractor involvement (ECI) services.

Waterman sustainability director Scott Brown, M.AIRAH, says the brief called for a lively, innovative and environmentally sustainable building, and included a number of ESD objectives.

The brief stipulated the incorporation of best-practice ESD to achieve a 5 star Green Star rating. Another aim was to provide a long-term, robust structure and service design to minimise both running costs and continuing maintenance requirements.

The design also had to be "best fit" to the university's requirements, with a stated aim of utilising the building as a live teaching aid – a living laboratory so to speak.

"At the start of the design phase, FEIT researchers were consulted on their future research goals and what they would require in the way of equipment to achieve this," says FEIT research laboratories manager Ray Clout.

"With the continued worldwide interest in energy re-use and conservation, FEIT decided that it should elevate its current research levels on this technology."

The nature of this equipment, and its intended use, meant it was imperative that collaboration take place between all stakeholders.

BINARY CODE AND URBAN PRESENCE

Of importance both to the architectural identity and performance of the FEIT building is its unique façade.

The angled, semi-transparent binary screens envelop the building – as well as overshoot the structure by up to 16m in some areas – to provide a "dramatic urban presence".

Each screen is made up aluminium sheeting, individually perforated with binary code – the series of zeroes and ones that underpin computer programming language.

When placed together, they constitute a message that is repeated around the building's façade.

Behind this façade, double-glazed low-e glass has been used.

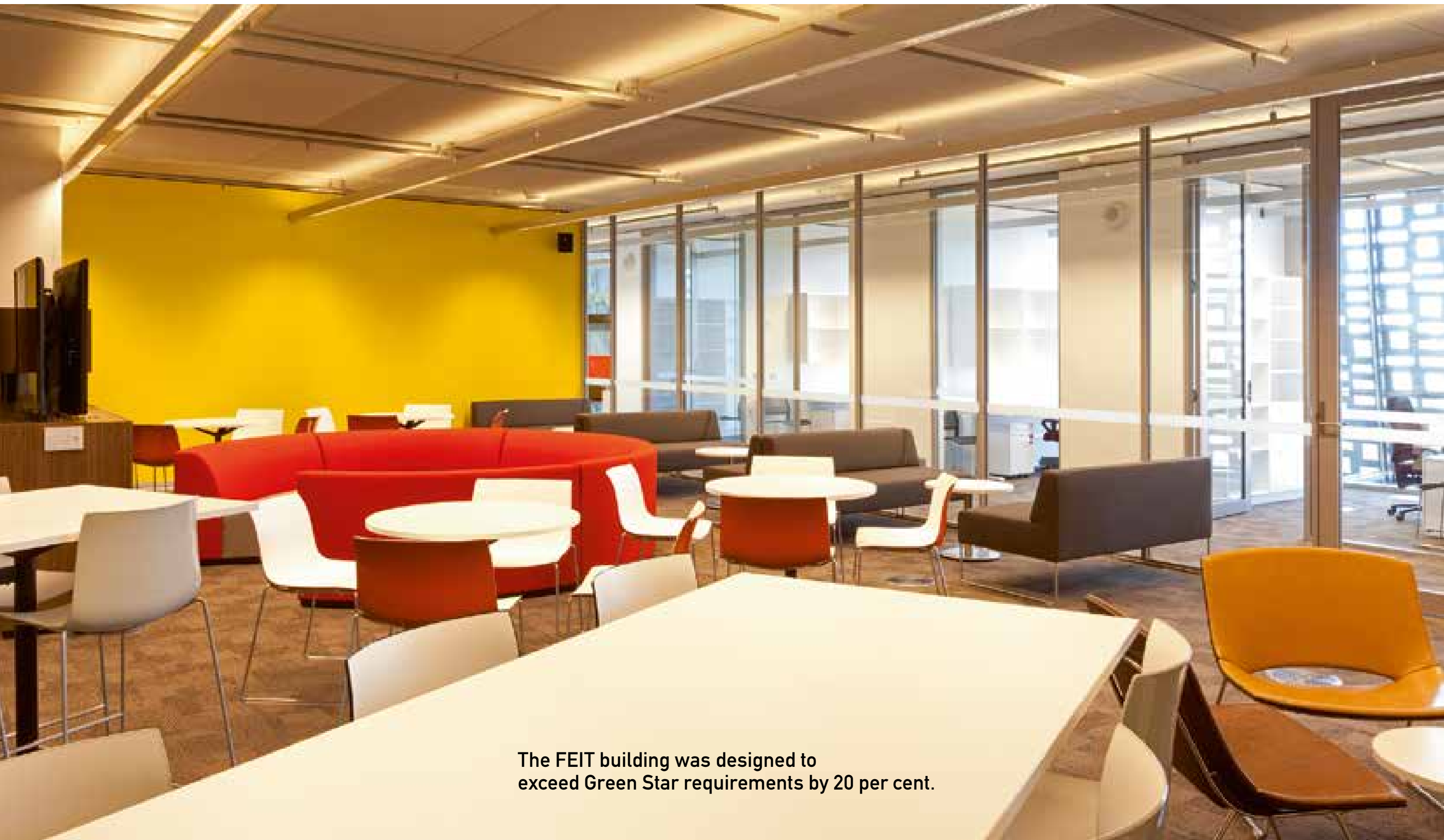
"The binary screen provides an external shading element that reduces solar loads by over 50 per cent," says Waterman's Scott Brown, M.AIRAH. "Daylight penetration is affected by the screen but is still significant around the perimeter."

However, Clout says it was clear that the highly esoteric nature of some of the equipment and its installation requirements were unfamiliar to builder and consultants, as well as to some members of the university's own building management team.

FEIT's own researchers were employed to design and install the hydrogen fuel cells, a technology in which they are world-renowned specialists.

SERENDIPITOUS GENERATION

A 5 star Green Star rating was sought, and the FEIT building was designed and modelled to exceed Green Star energy requirements by more 20 per cent. Yet for all this, the inclusion of renewable energy equipment was installed primarily as a research and learning tool.



The FEIT building was designed to exceed Green Star requirements by 20 per cent.

LESSONS FROM THE CONSULTANT

Waterman director Scott Brown, M.AIRAH, shares some of what he learned from the project.

1. Communication

Effective communication within the design team between consultants was paramount.

2. New systems

It can take some time for the design team, construction team, client and occupants to understand the requirements, effects and likely outcomes of non-standard and innovative building services systems because they have not been exposed to them before.

It can be difficult for some people to grasp, while others may find the change itself difficult to accept.

3. Hard yards

The more hard yards put in, the more satisfying the result.

These items included roof-mounted solar PV array, solar-thermal parabolic trough collectors, and a vertical-axis wind turbine.

The PV array is capable of offsetting about 40MWh per annum, based on 4.5 hours of reliable sunlight per day. The vertical axis wind turbine is estimated to offset 10MWh per annum.

A hydrogen fuel cell, organic rankine cycle (ORC) turbine and solar thermal cogeneration system were installed in the plant room.

The electrical energy generated by all these renewable sources was designed to be fed into a "mini-grid" that runs parallel to, but not connected to, the base building grid.

Outputs are fed into a purpose-built power control centre that charges two 50kW capacity flow-technology batteries. If all sources are operating at full capacity, the batteries can supply upwards of 450kWh per day – equivalent to the power used by 45 typical Australian households.

To aid plant sizing, FEIT settled on having about 20 per cent of the building's electrical consumption met by these sources. But Clout says such generation was never intended to be the primary purpose of the equipment.

"The installation was not conceived to produce energy for the building," says Clout. "The fact it does is merely a serendipitous side effect."

Some of these systems were purpose-built to FEIT requirements for researchers to have a test-bed and hands-on capability to conduct research into future energy sources and use.

"Students now share the same benefits as the researchers," Clout says. "Their lecturers can now show and tell, rather than be locked into textbooks and projector images.

"Simply put, FEIT considered that, as the purpose of the building was to create a lab, unlike any that were available to the faculty previously, energy performance targets were meaningless."

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LESSONS LEARNED – THE CLIENT

UTS FEIT research laboratories manager Ray Clout says collaboration is key.

1. Collaboration

Close collaboration between all stakeholders is imperative. Regular face-to-face meetings are key.

2. Specialists

Specialist consultants must be used and consulted where there exists uncertainty in the technology being installed.

3. Inclusiveness

It is wise to include, early on, the suppliers and manufacturers of complex, specialised equipment in any communications and consultation process.

4. Be unequivocal

The client must ensure at all times that the builders and consultants have clear, unequivocal instructions and information to ensure the client's expected outcomes are achieved.

LIVING LAB

The concept of a living lab was implemented at the earliest stages of the design process, so systems could be easily incorporated.

Thousands of individual sensors, meters and gauges were installed within the fabric of the building during construction.

More than 300 strain gauges were installed at strategic locations within the concrete to monitor stresses of the slabs, footings and columns over the building's lifetime. Ion electrodes are also placed alongside the strain gauges to monitor salt concentrations in the long term to determine the level of corrosion attack on the concrete's steel reinforcement.

THREE-DIMENSIONAL LEARNING

A key teaching aid in the UTS Faculty of Engineering and Information Technology (FEIT) building is the data arena – a teaching and learning theatre that comfortably accommodates 24 participants standing at the centre of the "drum".

One of only 12 similar facilities around the world, FEIT's data arena is reported to feature the most up-to-date technology of any of its contemporaries. It features a 10m diameter, 4m high 360-degree screen, and six high-definition 3D projectors to allow researchers to view their data (using 3D glasses) as a 3D image rather than simply numbers on a spread sheet.

With simple hand gestures, the user is able to interact with the displayed data to do almost anything they can imagine, including rotating, expanding, exploding and re-constructing the image.

Special effects such as different weather conditions, temperature changes and aromas enhance the user experience.

"The effects can be synchronised to the datasets used to display 3D images," says FEIT laboratory manager Ray Clout, "and give the user a real feeling of immersion."

The building features two large, tiered collaborative theatres, which each seat 200 students, and two smaller theatres accommodating 95 students.

These spaces facilitate multiple forms of engagement, including lecture presentation, collaborative group work and technology-enabled activities. Two work benches per tier are provided with moveable furniture to encourage group work.

For public display, the Disruptive Design Lab showcases the faculty's disruptive technology designs such as the Hypermon and Ventra Heart.

"Disruptive technology is considered to be that technology that makes current technology obsolete very quickly," says Clout. "The iPhone could be considered disruptive."

And on level 12, where the faculty's administration and Dean's unit is located, a wintergarden room provides a convivial atmosphere where visitors and guests are met.

It contains a series of vertical gardens that are watered by collected rainfall, as well as a time capsule that will be opened in 2045.

About 2,500 internal environment sensors have also been installed across all floors, as well as the building's carpark levels, to monitor comfort levels. And people counters are used to determine optimum space usage and movement patterns.

The building also features an external weather station.

"The information from all these sensors, meters and gauges collected, either via wire or wirelessly, and archived in a server database," says Clout. "The data is available to researchers and students to assist with their work or general interest."

Data considered of interest or of educational benefit is displayed on large screen monitors located across all levels and public spaces.

But monitoring is just a small part of the FEIT building's student-centric design.

Believed to be a first of its type in the world, the building's solar-thermal cogeneration system was designed and installed by specialist energy companies Solem Consulting and NEP Solar.

They were assisted by Waterman, which helped incorporate the system into the building's condenser water and chilled water systems, as well as the building management (BMS) and energy-management systems (EMS).

The system utilises roof-mounted solar-thermal parabolic trough collectors and the ORC turbine – a hybrid turbine based on scroll compressor technology. An absorption chiller, heat exchangers, buffer tank, pumps, PLC and SCADA controls are also used.

Organic fluid contained within the solar thermal parabolic trough collectors is heated by the sun to a high temperature before being used by the ORC turbine to drive an asynchronous electric generator to provide electricity to the building.

The fluid then leaves the turbine at a lower temperature and enters an absorption chiller, which provides chilled water to the building's air conditioning chilled water system. Once used by the chiller, the fluid still has enough heat to heat the hot water storage tank that provides hot water to supplement the building HW reticulation system.

Finally, the fluid returned to the solar collectors, where the process begins again.

Clout says plenty of interest has been shown by the university's researchers in using the solar-thermal concentrators and purpose-built chiller unit on the rooftop, for research into air conditioning use.

UNDERFLOOR SERVICES

Integral to occupant comfort across 95 per cent of the building is an underfloor air conditioning system.

According to Brown, architect Denton Corker Marshall's on-floor services reticulation design, which utilises raised floor voids rather than ceilings, was a major driver in the design of the building's HVAC systems.

For the Waterman engineering team, the challenge was delivering this in a relatively long and narrow building, which features a full-height atrium through its centre.

"The building services needed to be robust as well as energy – and water-efficient," says Brown.

"The raised-floor void space was tight and required to have ductwork, swirl diffusers, fan-coil units, chilled and heating-water pipework, along with other services, including power and communications cable trays, floor boxes and sprinkler pipework.

"Add to this soil drainage requiring fall, cold and hot-water supply, lab gases and

THINKING OF A MASTERPLAN

Ever since the New South Wales Institute of Technology became the University of Technology, Sydney in 1988, the Faculty of Engineering and IT had felt hamstrung by its accommodation on the city campus.

Spread across various buildings that displayed a "1960s public-service design mentality", physical and psychological barriers between staff and students had formed.

According to FEIT research laboratories manager Ray Clout, this had the effect of causing isolated pockets of research, and little collaboration between schools and units.

The removal of this barrier became a key design aspiration when, in 2009, architecture firm Denton Corker Marshall was engaged by UTS to design the FEIT building.

A key part of the brief was that staff, students, offices and labs under the same roof.

Located in the heart of Sydney's CBD, the final design settled on a 44,000 sq m building rising 12 stories above ground and four basement levels below.

With a total usable floor area of 23,500 sq m, the new building can accommodate about 5,000 students and staff in a mix of classrooms, theatres, research spaces and public areas.

The total construction cost of $190m was offset by support from both state and federal governments. As well as $50 million in funding provided by the Australian government, $1.2 million was provided by the NSW government's Department of Trade and Industry's Science Leverage Funding Program.

other services in the wet labs – it was a major coordination exercise!"

The final HVAC design settled on a decoupled system comprising of air-handling units (AHUs) and underfloor ducts for outside-air supply via swirl diffusers, which cater for part of the cooling and heating requirements.

Local underfloor fan-coil units (FCUs) are provided to boost cooling, as well as heating in perimeter zones. The AHUs provide about 50 per cent of the overall cooling (although this varies in different areas of the building) and all outside air heating in winter.

Chilled and hot water is provided via a trench in Jones Street from the university's central plant in UTS Buildings 1 and 2.

"Total capacity for the new FEIT building is approximately 3MW cooling," says Brown.

"Approximately half of the chilled water from the central plant serves the building AHUs, and the other half serves the underfloor FCUs via a secondary chilled-water loop at a warmer chilled-water temperature."

Similar to a chilled beam system, all dehumidification is provided at the AHUs to allow the underfloor FCUs to provide sensible cooling only. Although safety trays have been installed under the FCUs, they exist largely as a stop-gap, and are typically not connected to condensate pipework.

Spare capacity was built into many of the systems to allow churn and change of use within reasonable limits in the future.

One space not fully air conditioned is the building's crevasse-like, full-height atrium, which splits the building horizontally.

Located on the north side of the crevasse are the working laboratories, including power and machines, junior circuit labs, air conditioning and heating and health technologies.

On the south side of the crevasse, staff and student offices run in an east-west direction. Interspersed around the labs and offices are student quiet areas for relaxation, meals and contemplative work tasks.

> It is a live showcase … that will leave a legacy that will be used by engineering students and researchers alike for years to come

The atrium provides both pedestrian access and natural light to the building, and features a number of bridge links, stairs and escalators to encourage interactions and collaboration between staff and students across all levels.

It is used as a major air conditioning return-air path which, in conjunction with some spot cooling in a few areas, provides a moderated temperature environment. It acts as a large smoke-exhaust path, and features six fans to provide 250 cu m/s total air flow.

SETTLING IN

Given the live nature of the building's systems, the BMS is an integral component to the building's function and performance.

Level 13 plant room equipment, including chiller and ORC turbine, utilise a Modbus interface, whereas power and the electronic control centre is connected to the BMS via an HMI (human machine interface) using Modbus/BACnet protocols.

The EMS – an adjunct to the BMS – collects data from the thousands of monitoring devices throughout the building. Both systems will be centralised and integrated to all buildings on campus, with the FEIT building used as a model.

After opening in the middle of the year, it's no secret that the FEIT building has experienced a number of teething problems. But with BMS tuning still being finalised, Clout expects that as time goes by the occupant experience will evolve and improve.

"It is the opinion of many that the building was designed using a 'form before functionality' approach," Clout says. "But as time goes by and users settle in, this attitude is expected to change."

Despite such issues, the new UTS FEIT building is proof-positive of the efforts taken by leading Australian universities to raise their worldwide profile and attract the best students, academics and research partners.

And this can only benefit our industry into the future.

"It's not just another sustainable building," says Brown.

"It is a live showcase of current and emerging technologies that will leave a legacy that will be used by engineering students and researchers alike for years to come."

PROJECT AT A GLANCE

THE PERSONNEL

Architect: Denton Corker Marshall (DCM)

Builder: Lend Lease

Client: University of Technology, Sydney

Commissioning agent: NDY

Mechanical, electrical and ESD: Waterman

Thermal cogeneration consultants: Solem Consulting and NEP Solar

THE HVAC EQUIPMENT

AHUs: Fan Coil Sales

BMS: Alerton

Cooling towers: BAC

Diffusers (swirl): TROX

Fans: Fantech

FCUs: Trox

Fume cupboards: Dynaflow

Grilles: Air Grilles

Heat exchangers: Alfa Laval

Hybrid cooler: LU-VE Contardo Pacific

Pumps: Masterflow

Thermal cogeneration: NEP Solar

VRF (serving comms rooms): Toshiba