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INDUSTRY CORNER

TOWARDS A NEW MODEL FOR CLIMATE RESPONSIVE DESIGN AT THE UNIVERSITY OF THE SUNSHINE COAST CHANCELLERY

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INTRODUCTION

The ecology and climate of South East Queensland has inspired the development of innovative building design and construction practices for well over a century. A modern regional architecture has evolved since the 1970s where the building form and fabric embrace a climate responsive approach to design. This is becoming an increasingly important part of creating ecologically sustainable buildings and development. A core philosophy is to harmonise the building form and fabric with the site and climate thereby reducing ecological impacts and achieving energy efficiency whilst providing human health and comfort and creating opportunities for social interaction and a productive learning environment. The University of the Sunshine Coast in Queensland, Australia, has embraced an ecological vision from its inception. From the first steps of its master planning through to its newest building, the Chancellery, the University demonstrates an evolution of innovation that embodies the principles of climate responsive ecological design.

This paper first discusses some of the initial steps in this evolution, the University's vision, and master planning. Second, it presents the climatic data that forms the basis of the passive design strategies. The third section discusses the innovative design strategies and attributes of the Chancellery followed by outcomes from initial research on how these strategies have enabled it to meet its environmental objectives. The paper is intended to provide building design professionals and contractors with a new model for university buildings and campuses and to provide a case study for climate responsive design in warm temperate climates.

CHANCELLERY FAST FACTS

Location: University of Sunshine Coast, Sippy Downs, Queensland, Australia

Building type: Chancellery, Student Services, academic offices, classrooms, lecture theatre, café

Climate type: Warm temperate

Climate control: Mixed mode, displacement, air-conditioned, and natural ventilation

Floor space: Fully enclosed area: 3,105 m2, roofed semi-enclosed floor area: 1499 m2, total area: 4,604 m2

Number of floors: 3

Building budget: AUS$12.5 million

Opening date: 2006

Owner: University of the Sunshine Coast

Building population: 86 staff, 700 student teaching spaces (including 100 casual spaces to mezzanine), 50 café spaces

Architect: Architectus

Project Leadership: Mark Bradley (client representative), Lindsay Clare, Kerry Clare, and Gavin White

Mechanical, electrical engineers: Lincolne Scott

Structural Engineers: Taylor Thomson Whitting

Sustainable Design Consultants: Advanced Environmental

Project Design and Reporting Tools: Integrated engineering and architecture design approach,

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[3]Note: Unless noted otherwise all figures and photos are copyrighted by Architectus.

Revit, Ecotect (Shading design stereographic diagram analysis), Radiance (Daylight analysis software), TAS (Thermal Analysis Software)

Tertiary Education Facilities Management Association (TEFMA) Ecological Sustainable Development rating: 85/100 (USC 2007)

Awards: 2008 RAIA Sunshine Coast Building of the Year Award, 2008 AIA QLD Public Architecture Award, 2008 AIA QLD Harry S. Marks Award for Sustainable Architecture, 2008 AIA QLD Colorbond Award for Steel Architecture, 2005, 2006 TEFMA Benchmark Report on Environmentally Sustainable Development

BACKGROUND FOR CLIMATE RESPONSIVE DESIGN

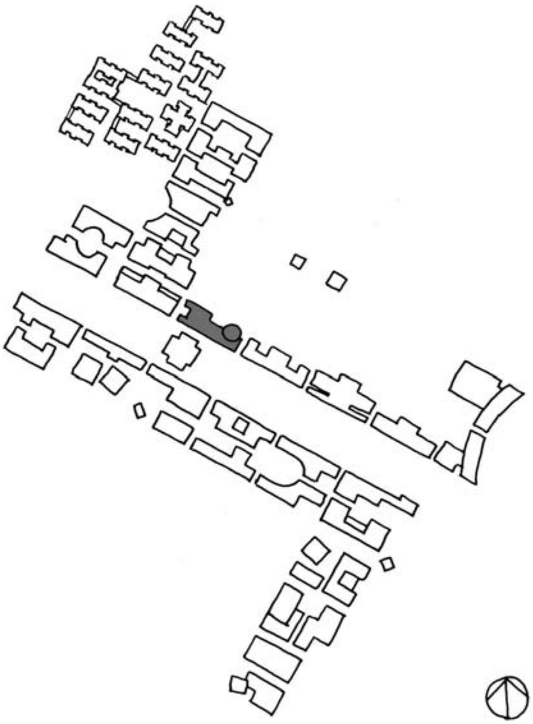
The Master Plan and Ecologically Sustainable Development

The University of the Sunshine Coast was established in 1994 to satisfy a need for quality public education in a growing region with a young population. Located on the site of a former sugar cane farm in sub-tropical Queensland, the Master Plan was completed by Mitchell Giurgola Thorp (MGT) Architects in 1994 in consultation with Geoffrey Pie. Formerly based in Philadelphia USA, Romaldo Giurgola relocated to Canberra, the capital city of Australia, after winning the Australian Parliament House competition held in 1979.

A variety of guidelines for sensitive climatic building design were developed including the use of shaded space and sun control, passive cooling through cross ventilation, and the use of lightweight exterior construction of low thermal capacity to avoid the accumulation and re-radiation of heat. A key objective of the Master Plan document was that all new buildings comply with the north east/south west orientation and be "designed to produce comfortable interior environments with minimal interference from artificial climate controls" (MGT Architects 1994, p.29).

FIGURE 1. South west facing shade veranda and central open space.

FIGURE 2. MGT Master Plan 1994 with Chancellery site shown in red (based upon MGT Architects 1994).



The key master planning goals were identified as:

- An ability to create a sense of place and an identity for the new campus within the early phases of development;
- A capacity to order long-term growth and change within a comprehensive but flexible plan;
- The use of land in a conservative manner;
- The support of passive environmental design principles for all campus buildings.

Initial buildings such as the Administration Building were constructed of double skin masonry and naturally ventilated whilst minimising active systems of climate control. Later buildings introduced a variety of passive cooling techniques including roof ventilation, courtyards, atria, solar chimneys, open circulation, breezeways, and wind scoops (Hyde and Rajapaksha 2005). In some cases buildings such as the University Library were air conditioned in response to the functional requirements for full climate control. It is important to recognise that this approach to the building designs was supported by the conceptual point of departure for the campus, namely the Jeffersonian planning concept.

FIGURE 3. University of Virginia, creating an "academical village" comprising visual, social, environmental qualities (Collins 2001).

Jeffersonian Planning Concept

The University of Virginia created a pioneering concept for campus planning based on the notion of an "academical village." When applied to the University of the Sunshine Coast, this approach, attributed to Thomas Jefferson, creates a visual, social, and environmental order to the campus. In particular the green space and associated axis is oriented perpendicular to 30° east of north exposing the long building elevations to summer afternoon cooling breezes and early morning winter sunlight penetration, whilst providing the green space with protection from the uncomfortable south to south-west winds in winter. Colonnades form the perimeter of the green space providing sheltered circulation (MGT Architects 1994).

The Jeffersonian concept is based upon the following principles:

- Linear form with a central and open common green space.
- Building entrances face the green space.
- Provides a framework for growth in the number of buildings and facilities.
- Distances between buildings across the green space are based on human scale and visual recognition (people can recognise each other from one side of the space to the other).

- Three-storey building height limit to the green space, with increasing height away from the green space.
- Recognition of the importance of indigenous landscape and biodiversity.
- Access of buildings to natural elements for cooling and heating.
- Planning of pedestrian circulation through arcades and circulation routes with a maximum travel distance, between the limits of the campus, of five minutes.
- Perimeter location of car parking and residential accommodation.
- Providing a sense of community and focus within the region.

The Jeffersonian planning concept demonstrates an environmental approach to master planning that is very clear within the University of the Sunshine Coast Master Plan, in the use of a central green space, an ordered approach to growth and pedestrian circulation within an external arcade. Social issues are demonstrated in the creating of a sense of place. The concept is particularly grounded in the climatic context of the location, which support and facilitate many of its principles.

CLIMATE AND DESIGN

Climatic Data

The University of the Sunshine Coast is located on a coastal plain with a warm temperate climate. Winters feature warm sunny days with night temperatures below the comfort zone, whilst summer conditions are more subtropical with humid conditions, overcast skies, and some monsoon rains. Rainfall events occur mainly in the summer period with a drier winter. A key factor of the Queensland climate is its high level of irradiation particularly in November and December when clear sky conditions can prevail. This creates elevated temperatures above 30°C and a high level of ambient and direct solar radiation. The number of days above 30°C is approximately 29 with temperatures as high as 40°C in extreme conditions. This combination of high temperatures and humidity highlight the importance of air movement in achieving levels of comfort.

The coastal location and topography around the University create a mesoclimate of sea breezes from the north east and south east, providing airflow through the site as shown in Figure 4. The sea breezes assist in moderating the high summer temperatures. In winter the southeast trade winds can create exposed conditions to the southeast quadrant of the site.

Climate Responsive Strategies

The principle climate responsive strategies found in Queensland to extend comfort zones using passive building features are:

- passive solar heating,
- cross ventilation,
- evaporative cooling and
- thermal mass.

These strategies are often combined to create passive building systems, such as linking high thermal capacity materials (thermal mass) for heat sink effects, with passive solar for winter heating and with cross ventilation at night for summer cooling.

Low thermal mass can be combined with ventilation and passive solar design to extend the comfort zone in summer and winter. Psychrometric charts for SE Queensland indicate this climate responsive strategy is limited in its application for cooling to about 30°C at high humidity and that heavy weight strategies and evaporative cooling are similarly limited. Given that the site features mean temperatures above 30°for nearly 30 days per year, additional strategies were needed to accommodate temperature extremes in summer and winter such as mixed mode ventilation.

The site planning principles that form the basis of the Master Plan and Chancellery designs are to orientate the buildings to minimise solar gain, reduce density, and modify the building massing to increase airflow through the site. Relatively high wind speeds are needed to achieve cross ventilation with rates of 1 m per second to achieve indoor comfort conditions. High humidity is a key climatic constraint of this site due to its coastal location and topography.

The master planning principles for the University have set up what appears to be a standardised visual and organisational hierarchy. However, the climate determinants across the site present very different conditions creating unusual opportunities for environmental design.

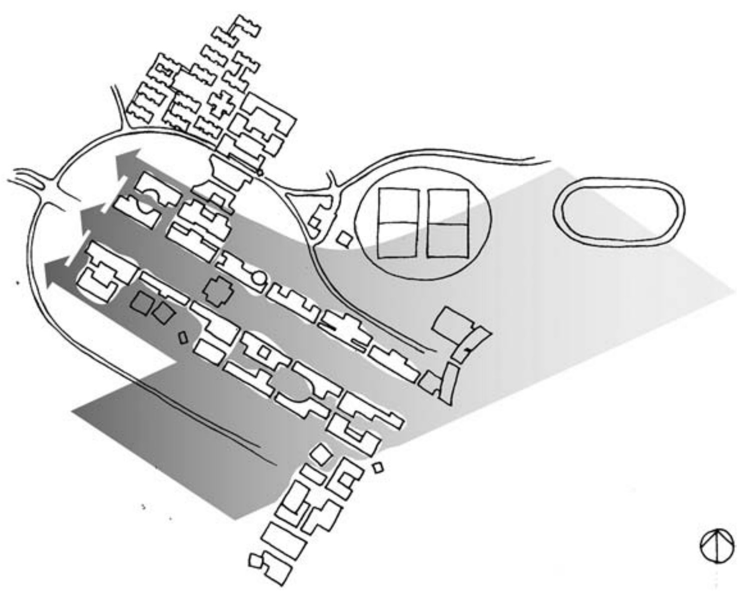


FIGURE 4. Airflow across the site (Hyde 2001).

CHANCELLERY CLIMATE RESPONSIVE DESIGN STRATEGIES

Building Planning

The site planning of outdoor spaces, streets and landscaping, and organisation of interior spaces to respond to specific climate and physical environments are key strategies of climate responsive design. Site micro-climate can be modified through site planning leading to improved thermal comfort of outdoor spaces, increased capacity for ventilation and sun control in buildings, and reduced cooling loads (Brooks 1988). Therefore, site planning and the organisation of interior spaces can directly impact indoor environment quality and resulting occupant health, comfort, and productivity. The siting and thermal comfort of outdoor spaces will also contribute to levels of social interaction and opportunities for outdoor teaching and informal learning.

Hyde provides climate matching strategies for buildings such as plan orientation, permeable wall and roof designs, thermal mass to floors, and the use of shade verandahs and courtyards (Hyde 2000). Research shows that plan dimensions beyond 15m reduce the effectiveness of natural ventilation strategies and lead to greater use of mechanical ventilation and cooling. Leaman also shows that smaller workgroups in individual rooms can lead to more improved productivity than in open plan work environments due to the higher level of ventilation and lighting control afforded to individuals in smaller spaces and a greater tolerance of thermal conditions (Leaman and Bordass 2005, Parts 2,3).

The Chancellery is planned as a series of climate responsive zones (Hyde 2000) from the external spaces to the buffer zone formed by the sunshading, louvres and shade verandah, to the passive zones able to be modified by light and ventilation without the use of air conditioning, to the active zones less influenced by the environmental affects of the external wall and windows and typically requiring air conditoning.

The Chancellery consists of four buildings as identified in Figure 5, separated by external breezeways beneath a mono-pitch roof. The overall external plan dimensions are 75m east to west and 34m north to south. Buildings 1 and 2 are between 7m and 8m deep and consist of staff offices and tutorial room areas organised as cellular perimeter spaces. Windows are oriented toward the north east providing optimum daylighting, solar access and summer solar control due to the high altitude of the sun in summer. The cellular organisation of space provides small populations and therefore a high degree of occupant control well suited to manually controlled mixed mode ventilation (AE 2005e). The long and

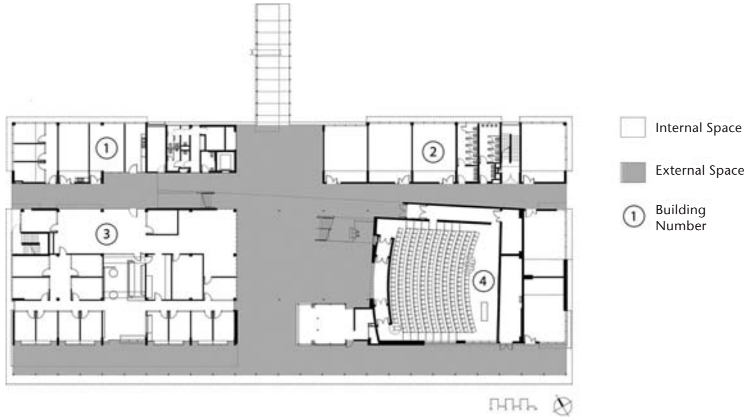


FIGURE 5. Ground Floor Plan.

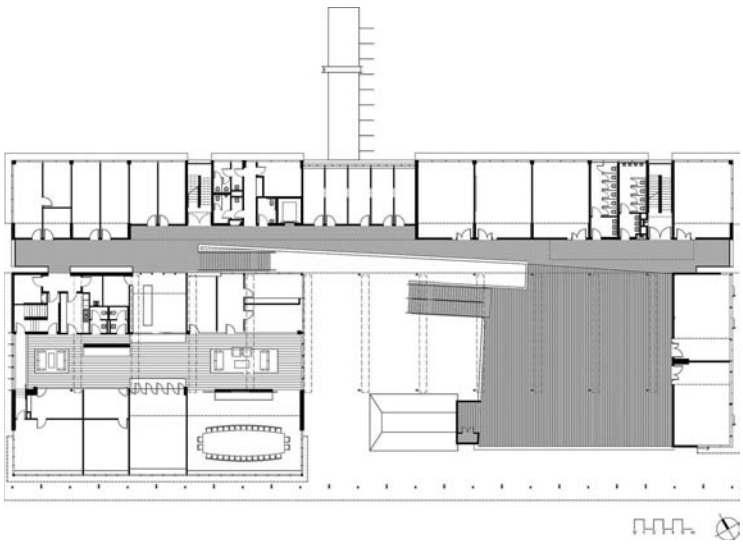


FIGURE 6. Level 1 Floor Plan.

thin plan shape encourages cross ventilation through rooms that can be enhanced by opening doors to the external breezeways whilst also contributing to a more sociable learning environment. Building 3 is 18m deep north to south and is occupied by Student Services at ground level and the Chancellery at level 1. Ceiling heights vary between 2700mm and 3300mm in height throughout, extending the effect of natural light and ventilation deep into the room. Building 4 contains a lecture theatre to the ground level and an outoor terrace to level 1 available to all students and staff across the campus.

Breezeways and stairs are treated as external naturally ventilated spaces. They are oriented east-west and north-south and act as "ducts" through which the breeze can be channelled (Hyde 2000). This provides comfortable thermal conditions deep inside the plan and reduces the effective depth of each of the four buildings to achieve more effective cross ventilation and daylighting.

The section of the building is open to promote ventilation cooling and the shedding of heat by stack effect. Connected vertical and horizontal voids and high ceilings and soffits minimise the effects of temperature gradients in the same way employed by Clare Design in the Buderim House (Hyde 2000).

A central outdoor space serves as a shaded meeting place and also acts as a semi-enclosed courtyard

FIGURE 7. Cross section looking east.

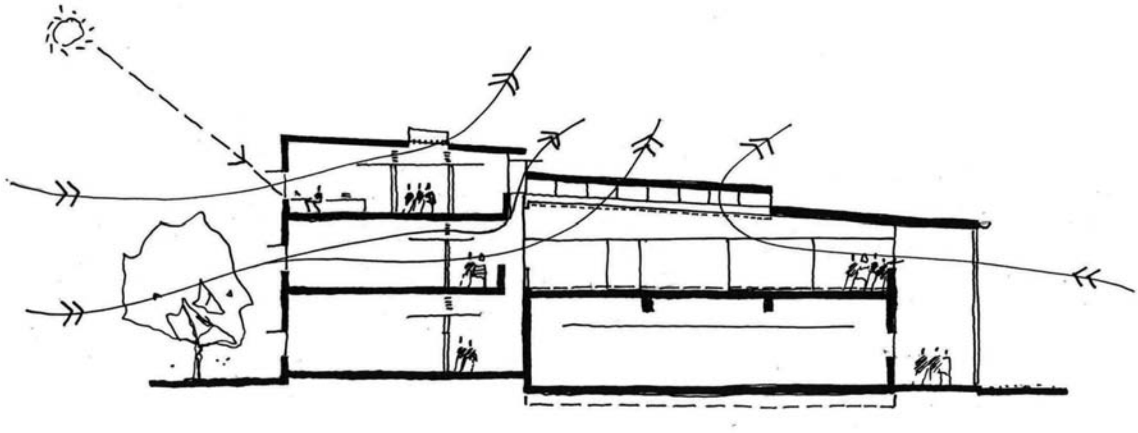
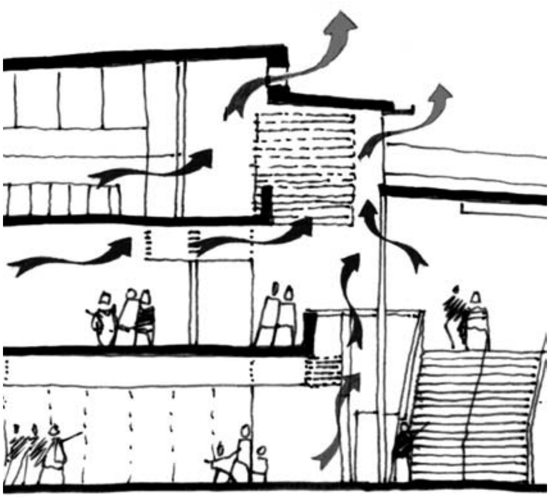


FIGURE 8. Cross section of breezeway.



that introduces light and ventilation into the building. The space is oriented toward the south west avoiding direct sunlight penetration for most of the year and is cooled by breezeway openings that channel air through the space. A concrete floor is shaded and provides thermal cooling to the space during the day, whilst the double height volume separates warmed air from the occupants. The ground floor is provided with a café, and the elevated first floor platform provides social and informal teaching space overlooking the University Green.

Natural Ventilation and Mixed Mode Climate Control

The University has taken the view since the establishment of the campus in 1994 that buildings should be "designed to produce comfortable interior environments with minimal interference from artificial climate controls" (MGT Architects 1994). Responding to this goal, a variety of natural ventilation strategies have been implemented in early buildings including the Faculty of Arts that experimented with natural ventilation techniques such as landscaped courtyards, wind scoops, and breezeway openings that together with varied air pressures and the stack effect achieve an air funnel effect to the courtyard. Operational energy use in the Faculty of Arts building was shown to be the lowest of five buildings in a study by Hyde and Rajapaksha (2005). Other buildings such as the University Library utilise air conditioning to ensure a stable environment for the book collection and constant thermal comfort in a deep plan building.

Natural ventilation can significantly reduce energy usage and green house gas emissions whilst reducing maintenance and operation costs. De Dear and Brager of the Center for the Built Environment at the University of California show that natural ventilation can also improve indoor environment quality compared to air conditioned systems as a result of higher levels of fresh air and greater occupant control (de Dear and Brager 1998). Studies indicate that the replacement of supplemental mechanical ventilation with natural ventilation or a mixed mode system can achieve health cost savings and productivity gains up to 18% (Brager and Borgeson and Lee 2007). Fisk reports decreases to Sick Building Syndrome (SBS) in office environments as a result of increased use of fresh air that could provide health cost savings of US$10 billion to US$30 billion in the USA (Fisk 2002). In the context of educational buildings higher levels of fresh air and air change effectiveness can improve indoor air quality and lead to improved learning outcomes (CHPS 2002). Fisher points to overwhelming evidence of the relationship between thermal comfort and academic achievement (Department of Education, Training and Youth Affairs) and Coward demonstrates the benefits of indoor air quality to environmental, social, and economic outcomes in adult education buildings, in his review of the literature (Coward).

The Chancellery is provided with a zoned system where each building incorporates a different conditioning strategy that responds to how each space is used and provides energy efficiency and indoor environmental quality benefits. These strategies provide varying levels of natural ventilation whilst promoting a high indoor air quality for the whole faculty with fresh air quantities exceeding the Australian Standard 1668.2 by 100%.

Mixed Mode Systems

Mixed-mode ventilation systems provide a hybrid approach to ventilation and cooling that provides outside air into a building by both passive and mechanical means to achieve cooling and heating. Natural ventilation is provided from operable windows, louvres, or dampers (either automatically or manually operated), and mechanical ventilation and cooling is provided from systems that include an air distribution system and refrigeration equipment. Typically natural ventilation is used when the weather conditons are suitable, and air conditioning is used when the weather conditions are too hot or too cold to rely on natural ventilation. A manually operated system allows occupants to decide when they prefer to use natural ventilation by simply opening the window. Simple controls such as reed switches can ensure that air conditioning systems are deactivated when windows are open. An automatically controlled system is more sophisticated with communication between a weather station, the natural ventilation openings, and the air conditioning system. Such a system will be pre-programmed to automatically close windows and switch to air conditioning mode when temperatures are too hot or too cold for natural ventilation. They will also automatically switch to air conditioning mode at the onset of rain or excessive wind (AE 2005d).

Mixed mode systems can provide many of the benefits of a natural ventilation system and can reduce fan and cooling plant energy consumption when compared to an air conditioned system by between 15–80% depending upon climate, cooling loads and building type. Systems vary significantly in design and are described in detail at the Centre

FIGURE 9. Level 1 breezeway and outdoor teaching mezzanine to left.

for the Built Environment's online resource (http://www.cbe.berkeley.edu/mixedmode/aboutmm.html).

Design investigations of thermal comfort were completed during the design development phase of the Chancellery to determine which passive design and natural ventilation strategies achieved the least number of hours of discomfort each year and thus reduced annual hours where air conditioning would be needed. It was determined that the use of 24-hour ventilation through night purging, combined with the use of exposed thermal mass, cross ventilation for teaching rooms, and ventilating skylights and clerestories in public areas, would achieve the best thermal comfort conditions (AE 2005e).

A combination of simple horizontal and vertical solar shading, internal blinds, thermal mass, and night-time purging maximise the period of the year during which natural ventilation can provide adequate cooling and thereby minimise the use of air conditioning. A site wide building management system (BMS) links to a local BMS panel within the building to control local air conditioning and ventilation plants such as the displacement system, toilet exhaust, and fan coil units to achieve energy and operational efficiency.

Offices and tutorial rooms are designed to operate with a mixed-mode changeover capability. Each room is provided with natural cross ventilation by means of operable sliding windows to the outer wall and an exhaust damper located at high level to the wall adjacent to the breezeway. Sun hoods are designed to provide weather protection so that windows can remain open during summer rain.

If desired by the occupants doors can be left open when rooms are in natural ventilation mode. Individual fan coil units provide heating and cooling from locations above doorways. Fresh air intake is provided from the naturally ventilated breezeways immediately adjacent to the fan coil units by means of high-level anodised aluminium grilles.

FIGURE 10. Cross section of typical office/tutorial room in natural ventilation mode.

If the occupants wish to use natural ventilation they can open a window (Figure 10). A reed switch disables the air conditioning, and opens the high level damper. The air conditioning cannot be switched back on whilst the window remains open. If the occupant wishes to change to air-conditioned mode, he must close the window and switch the system on by means of controls provided to each room. The reed switch will then close the damper above the door to improve efficiency of cooling in the room (Figure 11). Building management personnel are responsible for leaving windows open to allow night time purging during warmer months to remove heat that is built up during the day. The air conditioning system is controlled by the site wide BMS operating during standard business hours and fan coil units can also be shut down via occupant timer controls when rooms are unoccupied. The displacement system used in the lecture theatre space has an economy cycle for energy saving.

Being manually controlled, the mixed mode system represents a low cost, reliable, and simple solution to ventilation and cooling. The Chancellery provides the first example of a mixed mode ventilation system on the Campus and may represent an ongoing solution that responds to the university's goals of reducing energy usage whilst developing a sub-tropical architecture.

FIGURE 11. Cross section of typical office/tutorial room in air conditioned mode.

Air Conditioned Systems with Mixed Mode Option

The deeper plan spaces of the Chancellery and Student Services support higher levels of privacy and separation and are provided with air conditioning to provide maximum thermal comfort and control of indoor conditions, while maintaining a reduced level of mixed mode changeover capability. Fan coil units provide the flexibility for units to be switched off when certain offices are not in use or when weather conditions permit, providing significant energy conservation benefits. Units are located above offices and service areas and screened by Hi-Light (proprietary) horizontal anodised aluminium louvres. Offices are provided with individual thermostats and controls. Ventilating skylights above the chancellery exhaust relief air from the air conditioned space and provide night purge ventilation.

Offices are provided with natural cross ventilation and a level of individual control and flexibility by means of openable windows. Reed switches disable the air conditioning when a window is opened.

Displacement Supply Air Systems

Displacement systems introduce cooled and fresh air at floor level, allowing the air to remove heat and pollutants from the space as it warms and rises by convection before being expelled at high level (AE 2005d). This achieves higher indoor environment quality when compared to conventional systems that mix existing and supply air and also require less fan energy thereby reducing energy usage.

Displacement air conditioning is used in the Lecture Theatre to provide thermal comfort and control of indoor conditions. The central plant room provides conditioned air that is introduced at the floor level by means of grilles.

Natural Ventilation

The central outdoor space, the elevated outdoor teaching terrace, and the breezeways illustrated in Figure 16, and the stairs illustrated in Figure 12 are considered external spaces and do not require the same level of thermal comfort as indoor spaces. These are 100% naturally ventilated by means of openings to walls and roofs. Awning windows and permanently ventilating skylights above the breezeways and central covered space expel warm air by

FIGURE 12. Typical naturally ventilated open stair.

means of the stack effect whilst inducing additional air movement. This is of particular value on still days when cross ventilation based upon air pressure differences may be ineffective. These openings have inbuilt weather protection and are an integral part of the natural ventilation system, allowing hot air to be effectively removed from the public areas.

Lighting

Natural Daylighting

Natural daylighting can provide buildings with a unique quality where variability can add interest to building interiors and give contact with the outside world. Daylighting can also reduce dependency upon artificial lighting and thereby reduce energy consumption and cooling loads. Its distribution and excellent colour rendering properties enhance the

FIGURE 13. North facing façade indicating lightweight cladding, sun shading, and louvre system to stairs.

appearance of spaces, and the controlled entry of sunlight provides warmth in winter (AE 2005b).

Research has shown daylighting to be a significant contributor to indoor environment quality. Fisk shows that natural light is far more appealing to humans than artificial light and can provide increases in occupant health, comfort, and productivity (Fisk 2002). A CHPS study provides design principles for classroom design including the avoidance of direct sunlight and glare and planning for uniform daylighting (CHPS 2002).

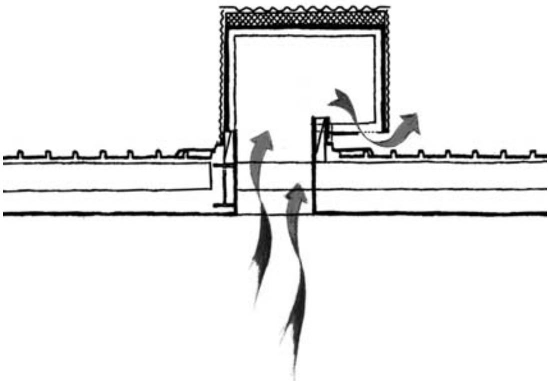
The Chancellery maximises the use of natural lighting through a variety of strategies and only supplements this with artificial lighting where necessary. The key planning strategy is the separation of the overall building footprint into four separate buildings covered by a large overhanging roof. The buildings are arranged to suit areas of more and less daylight availability. The teaching and office spaces, which represent the greatest amount of floor area, are oriented toward the north east and thereby provided with the most access to daylight whilst being separated from the car parking by a green zone to mitigate reflected light and glare. The Chancellery and Student Services are located to the southwest corner and the lecture theatre is positioned to the south east corner requiring the least daylighting. Skylights and clerestorey windows provide consistent daylighting to the building interior above the circulation breezeways and the social spaces between the buildings.

The façade design maximises the use of natural lighting to provide optimum visual comfort for occupants whilst minimising the need for artificial lighting. The strategy adopted was to maximise window widths to the full width of the rooms and specify 6mm clear float glass that offers a high visual light transmittance and control. The entry of direct natural light is controlled by maximising solar shading thereby ensuring occupant visual and thermal comfort (AE 2005b). Solar shading was designed with the assistance of stereographic diagram analysis, with the objective of preventing direct sun from hitting the façade from September to March between the hours of 10 a.m. and 4 p.m., in order to reduce heat gains and energy consumption. The resulting strategy is 800 mm deep horizontal sunshading fixed at the window head (1950mm above the floor), to all four elevations and vertical sunshading to the northwest elevation at 1200mm centres.

The central outdoor space, the elevated outdoor teaching terrace, and chancellery and breezeways are provided with natural daylighting by two skylight types. High level louvre windows to the breezeway are oriented toward the south west avoiding direct sunlight until afer 4 p.m. in summer. Innovative raised ventilating skylights (Figure 14) are provided to the lower roof, oriented toward the north west and southeast and clad in Alsynite Ultra Clear to maximise daylight levels whilst controlling glare from direct solar radiation. These are located at 7.2 m centres and are 1.0 m in height.

The results of the natural lighting investigations report completed during the building design phase indicate the building should experience good levels of natural light with daylight factors of over 2 in a

FIGURE 14. Typical ventilating skylight.



good proportion of spaces. This is considered an industry benchmark by the Green Building Council of Australia's Green Star Rating scheme. Low levels of artificial lighting were shown to be required to supplement natural lighting on cloudy days (85% diffuse). Office and tutorial rooms to the north could rely on natural light to provide adequate lighting until late afternoon throughout the year (AE 2005b). Blinds were shown to be required in winter to control glare. The lecture theatre and tutorial rooms to the southeast corner require low levels of supplementary lighting to boost lighting levels to 320 lux. Daylight conditions to the Student Services offices on the ground floor were assessed as poor and required supplementary lighting (AE 2005b). Light transfer panels were provided in the Student Services ceiling to transfer light from the central Chancellery space above; however, these are not operational in the current fitout.

Daylighting levels to Student Services may have been improved through the use of larger areas of glazing at ground level with suitable privacy screening to compensate for the high degree of visual separation and privacy required by the brief. Whilst the verandah roof provides a protected circulation zone to the south west elevation, it reduces daylighting levels to Student Services.

Artificial Lighting

New generation artificial lighting can reduce energy usage by delivering more light for less energy. Reduced heat wastage also contributes to reduced cooling loads and air conditioning costs. They can also provide an improved colour balance and increased lamp life whilst maintaining their peak brightness for most of their life.

Research has shown that new generation lighting can reduce operational energy use by more than 50%, and lamps can remain viable for up to four times that of traditional lighting. These efficiencies contribute to reduced maintenance and running costs (AE 2005b). The U.S. Department of Energy and the Rocky Mountains Institute published an influential paper in 1994 demonstrating that lighting design retro-fits were a major contributor to indoor environment quality, occupant health, and productivity (Romm and Browning 1994). Since that time multiple studies have shown the benefits of new generation lighting (Paevere and Brown 2008).

New generation T5 tri-phosphor fluorescent lamps were provided throughout the faculty. Lighting controls and sensors are provided to each room that automatically switch off lights when daylighting levels are sufficient or when rooms are not occupied.

Daylight studies completed during the building design phase indicated that the office and tutorial rooms would achieve high levels of daylighting thereby minimising the need for artificial lighting.

Thermal Mass

Thermal mass can reduce the internal temperature fluctuation by acting as a thermal sink and plays a key role in mixed mode buildings. Thermal mass is only effective where the concrete or masonry is exposed to the occupied space. Internal finishes such as carpet and plasterboard can therefore not be used (AE 2005c). Thermal mass provides maximum cooling benefits when integrated with night purging where the daytime heat gains from radiated heat, occupants, and equipment are replaced by night coolness that is then released slowly from the concrete during the following day (Hyde 2000).

Thermal design studies completed during the building design phase proposed the use of heavy masonry or concrete walls to the external fabric. Further design development lead to high levels of internal thermal mass, protected from solar gain and high external temperatures by a lightweight façade cladding and insulation. The exposed concrete floor slabs and columns and the partly exposed soffits assist in stabilising internal temperatures by absorbing internal heat generated during the day (Hyde 2008). Breezeways serve as cool islands providing cool air and air movement to the occupants and supplying the fan coil units to the adjacent rooms.

Building Envelope

The primary role of the façade in a hot and humid climate is to minimise heat gain from solar access whilst also providing maximum diffused daylighting. The secondary role is to provide ventilation whilst providing protection against rain penetration (Hyde 2000). The building envelopes of earlier campus buildings are typically constructed of cavity masonry.

Research shows that the use of lightweight cladding, high levels of insulation, and carefully designed sun shading can provide visual comfort, minimise heat gains, and maximise thermal comfort whilst reducing plant requirements, energy consumption, and carbon emissions. Heat gains can be further reduced by minimising the area of wall exposed to the sun, by means of orientation. Shorter opaque walls can be oriented to the east and west where solar heating potential is greatest due to low altitude sun. Longer transparent walls can be oriented toward the north (south in the northern hemisphere) where the solar heating potential is reduced due to the higher solar altitude (Hyde 2000).

The Chancellery building envelope has been specifically designed to suit the local climate thereby requiring less intervention from mechanical services to heat and cool the interior spaces.

The façade consists of a single skin of corrugated Zincalume™ coated steel as illustrated in Figure 15 and clear finished compressed fibrous cement. Breezeway walls are clad in dark stained exterior grade plywood (Figure 9). External and breezeway walls are insulated with foil backed mineral wool with an R-value of R2.

Glazing units can be opened by the occupants to provide natural ventilation. Each office is provided with a window and corresponding damper, each with a free open area of 0.39 m^2. The larger tutorial rooms are provided with windows and dampers each with a free open area of 1.75 m^2. Performance glazing is not required to the façade as a result of the external sun shading, and windows are therefore constructed from a single pane of clear float glass.

The roof and shade verandah protect the building and circulation from most rain conditions, reduce solar gains during the day, and promote cooling at night-time (Figure 1). The skillion roofs drain high volumes of rain in short periods whilst promoting the movement of warmed air upward toward the high level ventilating louvre windows and vents. Potentially high levels of solar radiation through the roof are offset by the use of reflective light coloured Zincalume™ metal roofing and foil backed insulation with an R-value of R3. The skylights ventilate

FIGURE 15. Entrance and north facing façade.

warmed air whilst the shade verandah shades the façade and diffuses daylight to the building interior.

Sun hoods shade both the glazing and the façade from September to March between the hours of 10 a.m. to 4 p.m. (Figure 13). Direct sun penetration into the building in wintertime is encouraged for thermal reasons. Sun shading consists of 800mm deep fixed horizontal sun shades made from 6mm aluminium.Visual comfort and glare can be controlled by the occupants through the use of blinds, and fixed timber screens provide sun breakers to the south elevation (AE 2005b).The combination of sun shading to all elevations, the verandah shade roof, shading from adjacent buildings, and the recessing of spaces to the south, serves to minimise the area of wall surface exposed to the sun.

Other applications of lightweight cladding and high levels of internal thermal mass include the Cotton Tree Housing Development by Clare Design at nearby Cotton Tree on the Sunshine Coast (Hyde 2008). Though not common on the Sunshine Coast, this form of construction is ideal for hot climates with high levels of solar radiation, high diurnal temperatures, and frequent rainfall.

Building Materials

Building materials consume natural resources during manufacture and transportation to site. Issues that need to be considered by designers include their embodied energy, life cycle costs, levels of maintenance and replacement, and their potential for reuse in future applications. Materials can also contribute to SBS through the emission of gaseous pollutants, micro-biological contamination, and dust and fibres (GBCA 2008).

The materials selected for the Chancellery are simple, durable, and affordable providing an architectural language of lightweight appearance suited to the coastal setting, whilst providing internal thermal mass to stabilise temperatures.

Benchmarks for material selection were based on some of the Green Star indoor environmental quality, material, and emission credits. At the time of design the Green Star Education tool was not in existence. Design initiatives targeted the reduction in the use of PVC, old growth timbers and finishes with high levels of Volatile Organic Compounds (VOC) such as carpeting with solvent based adhesives. Other measures included the reduction in the use of insulation manufactured with CFC and HCFC, which can contribute to the depletion of the ozone layer. The widespan structural steel frame construction provides future proofing by enabling planning changes to the building in the future.

The Chancellery provides an integrated engineering and architecture design approach that considers the potential of materials to provide thermal comfort and enhance indoor environment quality.

FIGURE 16. Central outdoor space, café, and elevated outdoor terrace with University Green beyond.

PRELIMINARY ANALYSIS

Operational Energy Conservation Efficiency and Abatement

The Chancellery is currently being examined by Hyde with regard to benchmarks for operational energy use and the extent to which it follows a tiered approach to energy use. This study will recognise different sources of energy (renewable and fossil) and the grade of energy. Lower grades of energy include thermal energy from the sun and higher grades include electrical energy, which have a wider range of uses.

The priority in the design of the Chancellery has been this tiered approach to operational energy conservation through the use of passive design systems. Energy efficiency measures were also adopted in the selection of the active systems. Finally, an overall abatement of fossil fuel energy-use was achieved by reducing the need for energy solutions.

Abatement of Fossil Fuel Energy

The application of various strategies for space conditioning, including change over mixed mode and displacement systems, provides significant energy savings. The total building energy use is expected to reflect around 0.48 GJ (133 kWh) per m^2 this year based on the 2008 TEFMA return. The energy use of larger universities is approximately 0.55 GJ (152 kWh) per m^2 per year (TEFMA 2008).

Whilst it is expected the Chancellery will provide figures below other fully air conditioned spaces on campus, it should be remembered that these buildings include a considerable proportion of non-air conditioned space, and this should be taken into account in the energy analysis.

Energy Usage Analysis—Lighting Thermal and Ventilation Study

An initial study of the Chancellery is being undertaken by Hyde using the Lighting Thermal and Ventilation (LTV) tool (Hyde and Pedrini 2002, 2001). This tool utilises a multi-zone analysis to provide predicted energy consumption through synergies between active and passive systems. The analysis is based on a matrix simulation using DOE-2.1E and Superlight. The tool does not provide absolute values for predicted energy consumption as it is largely aimed at providing relative values from comparative studies to test combinations of passive and active system scenarios as shown in Figure 17. The analysis is sensitive to input parameters such as floor area, window to wall ratio, shading system, and orientation. The predicted energy consumption is then converted into CO_2 emissions

The preliminary study examined the energy performance of teaching spaces and office spaces in Buildings 1 and 2 on level 2. Two alternatives were modelled for each building, firstly a mixed mode with free running periods and air conditioned periods and secondly an air conditioned mode. The assumptions were as follows:

1. Natural ventilation (free running) mode for 75% of the time and air conditioned mode for 25% of the time.

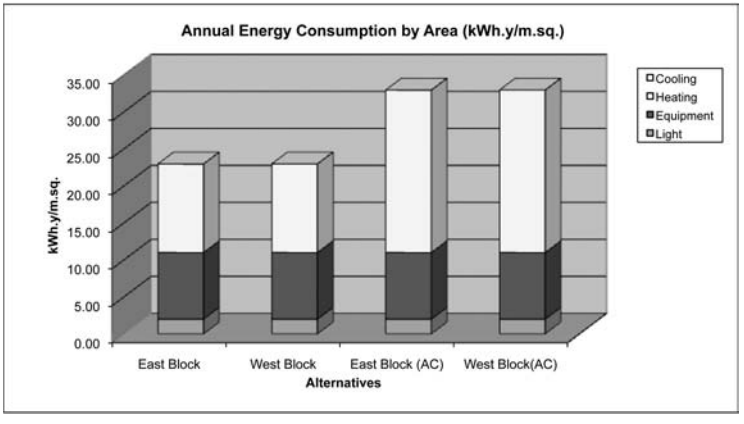


FIGURE 17. Initial results show the CO_2 emissions Buiding 2 (office space) and Buiding 1 (teaching spaces) in free running mode and air conditioned mode.

2. Full air conditioning with no natural ventilation.

The results show, as expected, an improvement in the energy consumption with the mixed mode ventilation approach. Questions remain as to the thermal comfort provided by the building in its free running mode and whether the building occupants utilize the system to optimise their own comfort and/or to minimize energy use. These issues may be addressed in future studies. The reasons for using a mixed mode ventilation system in this building are not only to reduce CO_2 emissions but also to improve indoor environment quality. Therefore, it is also necessary to consider the nature of the internal materials and finishes in terms of their health and environmental impacts.

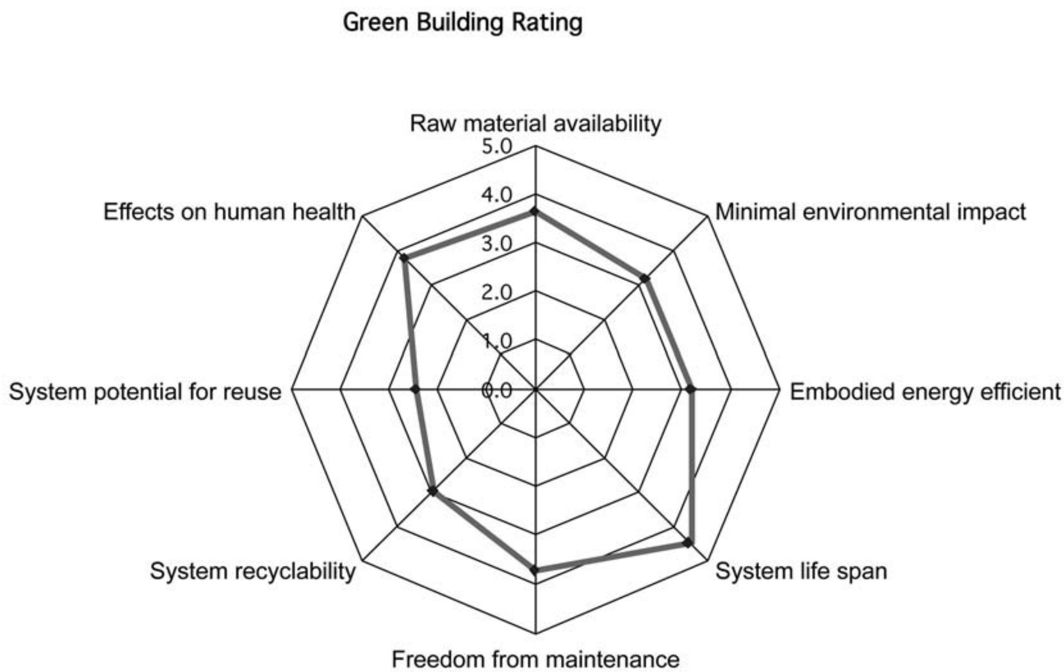
Green Materials Study

A Green Materials Rating was completed achieving an overall rating of 3.425 of a maximum possible score of 5.0. The Green Rating demonstrates the Chancellery performing well in terms of long life span and minimal effects on human health. The potential for re-use and recyclability of materials is indicated as low, however, this would be expected to be higher than the rating for other buildings on the campus due to the use of a steel portal frame and prefabricated façade materials. Other campus buildings are typically constructed of cavity masonry. The analysis does not consider systems design, which would be expected to compensate for the lower material scores.

CONCLUSION AND FUTURE STUDIES

This case study demonstrates that climate responsive strategies such as natural ventilation and the use of daylighting can provide sustainable and sophisticated outcomes where they are well designed and engineered. This approach is consistent with the University's original vision, master plan, and building design guidelines. The Chancellery advances this approach through the extensive use of naturally ventilated outdoor circulation, teaching, and social spaces. The design combines natural ventilation with mixed mode systems to achieve occupant

FIGURE 18. Green materials rating uses scales of 1 = poor to 5 = excellent (Lawson 1996).



comfort whilst minimising dependencies upon air conditioning, reducing energy use and operational costs, and improving learning outcomes.

This approach also provides opportunities for social interaction and learning within indoor and outdoor spaces that are comfortable and enjoyable to be in. These strategies may provide an ongoing model for university buildings in warm temperate climates and avoid the need for energy intensive climate controlled environments in buildings that typically consist of large numbers of small teaching spaces and offices.

Preliminary energy studies indicate the various strategies for space conditioning, including change-over mixed mode and displacement systems, provide significant energy savings and high levels of occupant control. The total energy use is expected to reflect around 0.48 GJ (133 kWh) per m^2 per year where the energy use of larger universities is approximately 0.55 GJ (152 kWh) per m^2 per year. These systems would also be expected to result in improved occupant health, productivity, and academic performance. This could be investigated in future studies.

Finally, the completion of a post occupancy evaluation would be expected to provide valuable feedback from building occupants and managers and contribute to improvements in sustainable campus building design in the future. The Chancellery provides an excellent case study of how climate responsive design can contribute to sustainable learning environments.

The iterative process led by the architects provided not only a quality design but also resulted in a practical outcome that has even exceeded our high expectations. For all its various occupants, and for all its various purposes, the Chancellery Building works outstandingly well. The materials, the features to maximise natural ventilation and minimise air conditioning, the provision of new kinds of social space—and the list goes on—all contribute to this being the most sophisticated building on the University campus, and advances our pursuit of efficient sub-tropical projects that we have engaged in, in a context of being an "architectural laboratory" since initial planning of the campus in 1994.

—Professor Paul Thomas
AM Vice-Chancellor, December 2008

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