Environmentally responsive building design

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ABSTRACT
Historically, the perception in Australia was that low energy and environmentally responsive buildings were inferior, more expensive and provided insufficient latitude for innovative design when compared to more traditional designs.

While there is considerable will to adopt an environmental design approach, it has been the inability to accurately benchmark or assess performance of a design that has held back its general application in building design.

However, with the 2000 or '*Green*' Olympics, the advent of industry recognized benchmark or rating systems and factors such as the recent sustained drought throughout Australia, has seen an increasing demand by clients for environmentally responsive buildings.

Through the use of case studies this paper will present some of the more recent innovative design responses. Insight will also be given into how the advancements in computer simulation are being applied to allow for the earlier and more comprehensive assessment of design concepts.

INDEX TERMS
Environmental design in Australia; Innovative design solutions; Computer simulation; Thermal comfort; Performance assessment

ENVIRONMENTAL BUILDING DESIGN IN AUSTRALIA

Environmentally responsive building design has taken significant steps forward in Australia in the last 10 years. Whereas 10 years ago the attitude to environmentally responsive building design was mostly lip service lacking any true substance, there is now a ever increasing focus on tangible outcomes.

With the advent of industry recognized rating tools such as the Australian Building Greenhouse Rating (ABGR) scheme as well as other environmental assessment systems which require independent assessment, building designers are now being challenged to strive towards best practice.

Rather than stifle innovation the requirement for independent performance rating of building designs is being seen by building designers as an opportunity to design buildings that are not just more environmentally responsive, but have a greater focus on indoor air quality, comfort as well as occupant satisfaction and interaction.

Although a lot of the rating tools and benchmarks within Australia focus on either greenhouse gas emissions or energy consumption, due to the relative ease by which it can be measured, there is now a move toward a more holistic approach to assessing performance.

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Taking the lead from the 2000 or '*Green*' Olympics, development authorities and councils are now imposing planning overlays outlining the design response requirements for development in respect to Ecological Sustainable Development (ESD). One such group is the Docklands Authority which oversees development within the Melbourne Docklands, which has brought out an ESD Guide for developers. This guide provides guidance to developers, be it residential or commercial, on ESD design elements as well as a Rating Award Scheme to benchmark/rate a developments ESD response.

Another influencing factor has been correlating evidence to overseas studies that buildings that have included environmental consideration in their design are being perceived as more comfortable by their occupants, achieving reductions in absenteeism and increased productivity as well as producing very innovative design solutions.

APPROACH AND METHODOLOGY

However, in meeting this demand for environmentally responsive buildings, designers must address some unique design issues most notably the wide range of climates within Australia.

Due to the vastness of Australia the prevailing climate from city to city and state to state is considerably different. Each state offers unique climatic conditions and seasonal variations to which the building designer must respond to in order to ensure year round environmental responsiveness and comfort.

For example, while Melbourne in Victoria enjoys a *warm temperate*, Darwin in the Northern Territory (NT) has a *tropical* climate. However, both Victoria and the NT have cities which have climates which would best described as *hot dry*. At the same time the design needs to be cognisant of local climatic phenomenon such as in Melbourne where it typically experiences two weeks in summer where air temperatures are the high thirties and it is not uncommon for it to reach 42–44°C.

However, unfortunately to further complicate things for building designers, there are limited locations in Australia where hourly weather data (i.e. Test Reference Year (TRY) weather data) for a whole year for use in performance assessment (i.e. computer simulation) of active and passive solar energy systems, annual energy consumption and indoor climate calculations.

For example the two most populous states Victoria which covers 227 416 km^2 has only six sites, two of which are in Melbourne and New South Wales which covers 800 642 km^2 has 11. Less populous states and territories have even less with the Northern Territory having only three sites to cover 1 349 129 km^2 and Western Australia which covers 2 529 875 km^2 has 16 sites.

Climate Analysis

Building designers have therefore had to find alternate means to find appropriate or representative weather data which can be used to test the suitability and annual performance of design solutions. While drawing upon local knowledge is useful and sometimes essential, other approaches are still required to enable designers to design climate responsive buildings.

One such approach which has been to compare the climates averages (i.e. temperature, humidity, rainfall, sunshine hours, wind speed and direction) for the location without annual hourly data with a possible representative sites having full hourly weather data. A sample of the results from this type of comparative analysis is shown in Figure 1

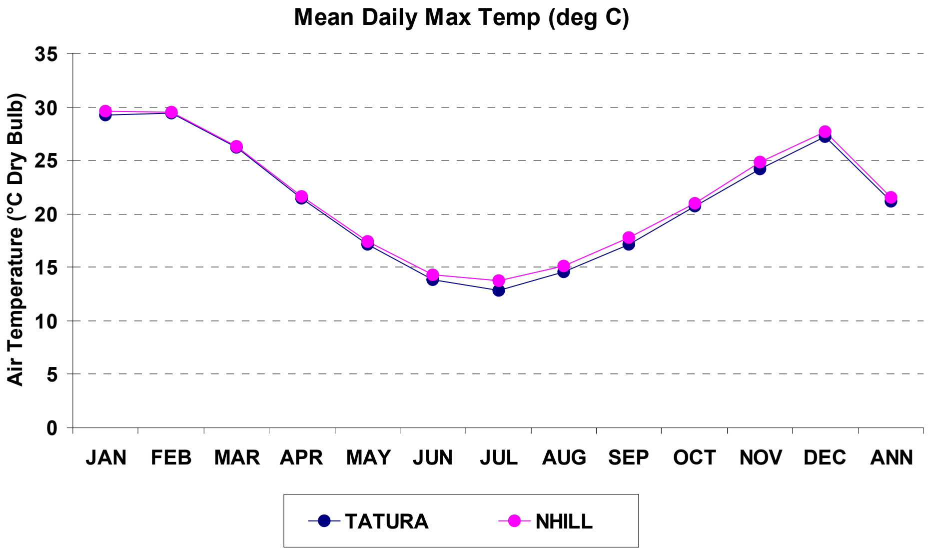

Figure 1 Mean daily maximum temperature comparison.

Through this approach a representative TRY weather file can be sourced and used as the basis of annual comparative performance assessments. Thereby providing the building design with a means to performance assess alternate constructions, fenestration solar, shading solutions and potential use of natural ventilation.

Design Tools

As with all aspects of building design, building designers are challenged to manage client risk. Environmental responsive designed building are no different, in fact it can bring new risks to the fore.

For example, the introduction of openable windows to facilitate the use of natural ventilation for comfort control during periods of mild weather raise design issues such as *controllability*, *ownership*, *air quality*, *noise*, *security* and most importantly *user preferences*, which must be addressed by the building designer. While these issues are essentially just design issues to be resolved by the building designer, unlike traditional air conditioned buildings there is a fundamental need for the client as well as the users to accept their responsibility in the effective use of openable windows.

Therefore, to assist designers to manage and address these design issues sophisticated computational software is being applied. Although numerous of different software packages are being used, they can be generally characterized into the following areas of assessment:

- *Dynamic Thermal Analysis*, to predict annual energy consumption and environmental performance in terms of predicted comfort within buildings. Used to compare alternate construction methods, insulation levels, façade treatments, presence of thermal mass, extent/types of fenestration as well as natural ventilation and night purge strategies. The more sophisticated software's allowing for the modelling of the convective and radiant impacts of lighting, equipment, heating and cooling systems.
- *Daylight Assessment*, to test the performance of daylighting design concepts in respect to predict daylight penetration and identify potential glare risks. Software packages typically generating photo realistic visualizations of spaces.

- *Solar Shading*, design and assessment to optimize their configuration to provide effective solar control in summer and the ability to collect solar heat in winter.
- *Computational Fluid Dynamics (CFD)*, used to provide a more detailed understanding of air movement through and comfort control within a room or space.
- *Plant Simulation*, detailed performance analysis of heating and air conditioning systems and their associated control strategies. Typically the systems can be superimposed on thermal analysis models to account for the passive design response of a building design.

CASE STUDY REVIEW

By way of insight into the application of the above advanced computer simulation and innovative design responses being taken in building design in Australia, the following provides overview of some recent building case studies. In each case samples of the analysis models used in the design of the buildings are provided, which will be further elaborated on during the formal presentation.

Monash Science Centre

The new Monash Science Centre will serve as common ground to bring research scientists and primary/secondary students together, encouraging their interaction and promoting an exchange of ideas and information. It will enable the general public to understand as well as be involved in research programmes, field excursions and other science related activities.

Sited on a green field site, the building comprises of two main pods: a classroom wing and exhibition hall. While the design philosophy for each pod of the building was the same the design responses were unique to their intended function.

Hydronic underfloor heating is used throughout, below the timber floor for winter comfort control, chosen for its ability to respond quickly to potential high occupancy. With all heating requirements provided by a geothermal field within an adjacent permanent retard basin. For summertime comfort control, the exhibition hall combines cross flow ventilation/stack ventilation strategy and the classrooms uses both single sided and cross ventilation. The relative performance in respect to energy, comfort and demand of alternate construction materials as well as the natural ventilation strategies were assessed using the thermal analysis software TAS (refer Figure 2).

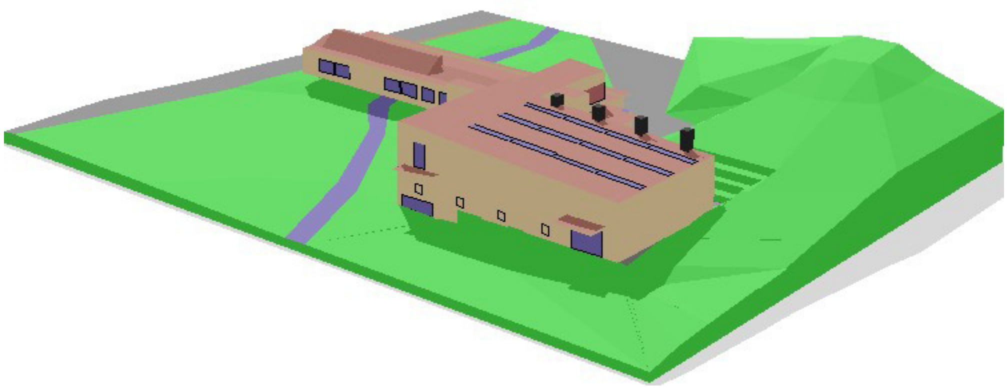

Figure 2 3D thermal analysis model used to carry out performance assessments.

The final design solution is now constructed and a photograph of which is shown in Figure 3 has been in operation for nearly 12 months. The building has performed extremely well both in winter/summer and users have expressed extreme satisfaction with the distinctly fresh and comfortable ambience being achieved.

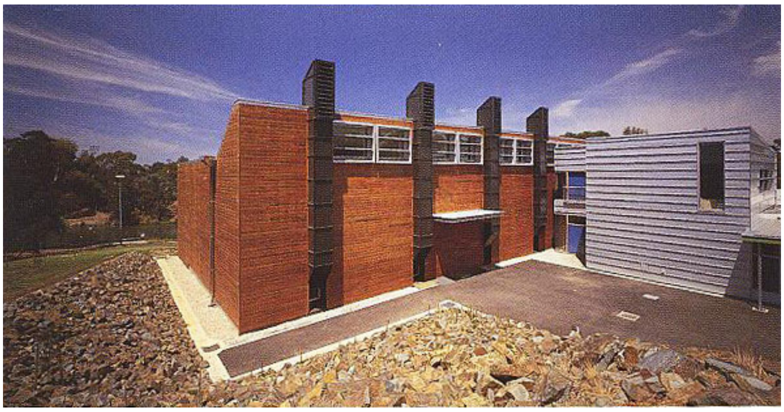

Figure 3 Photograph of constructed centre showing thermal chimneys to exhibition hall.

DNRE Sunraysia Horticulture Centre, Mildura
The new administration building to the existing facility is nearing final completion and represents a consolidation of previously dispersed regional services within the Department of Natural Resources and Environment.

The final design solution has achieved a true 'hybrid' ventilation strategy to all open plan offices which sees the use of air conditioning during periods of hot/cold weather and natural ventilation during milder weather. The design has also integrated thermal labyrinths below the building to act as passive climate modifiers of incoming outside air as well as effective daylighting strategy, which combines, optimally configured perimeter glazing and clerestory windows down the centre of the building. A perspective view of the 3D thermal analysis model used to optimize the configuration of the thermal labyrinth, the natural ventilation strategy as well as construction materials is shown in Figure 4.

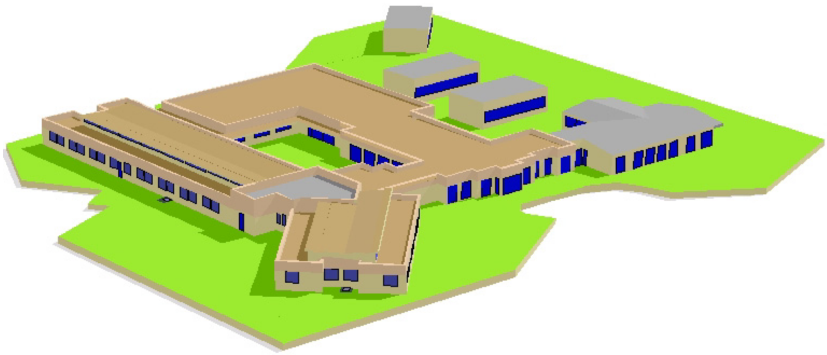

Figure 4 3D thermal analysis model of existing building and proposed extension.

Modernization of DNRE Regional Institutes
Modernization of the Department of Natural Resources and Environment Dairy Research Institute at Ellinbank, Regional Offices at Horsham and Regional Tatura Offices. The integration of environmentally responsive design principles was a key requirement and client objective for each of the projects and led to highly innovative design solutions. Independent review of the environmental design solutions, were also a key client driven requirement of the project.

In the case of the Dairy Research Institute at Ellinbank the design has seen the provision of non-refrigerative air conditioning through the combination of a thermal labyrinth and creek water storage system provide all necessary cooling during hot weather for the main administration building.

The integration of glare free daylighting, natural ventilation, night-purge strategies and in particular water conservation/re-use were also a general outcome from the design of each facility. Considerable attention was also given to the environmental impacts of material selection and waste management. Sample results from the daylighting analysis and a perspective view of the 3D thermal analysis model used to optimize the building design can be viewed in Figures 5 and 6.

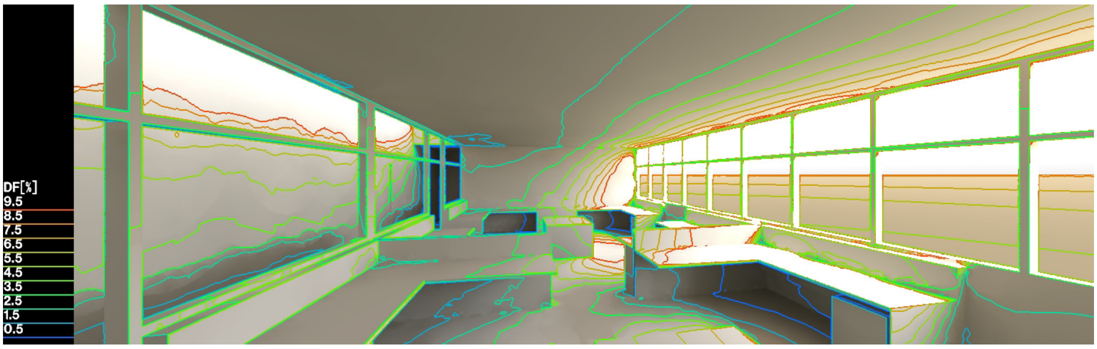

Figure 5 Daylight penetration analysis in farm systems offices in DPI/DSE Horsham.

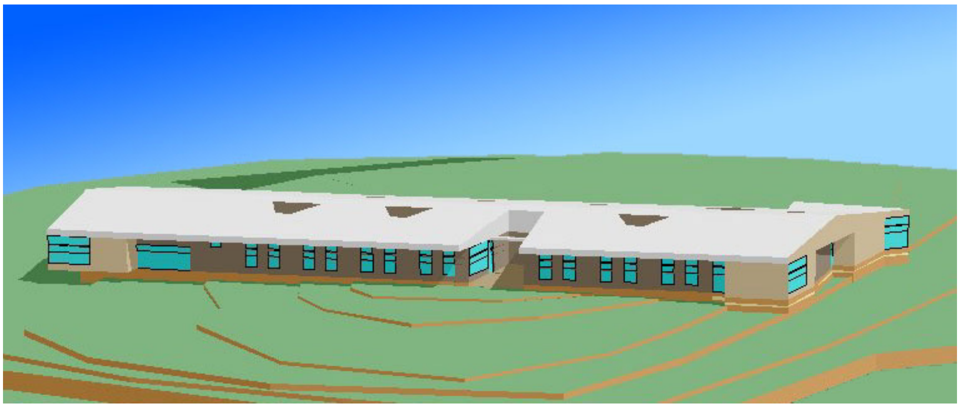

Figure 6 3D thermal analysis of main office building at DPI/DSE Ellinbank.

CONCLUSIONS

- *Low environmentally responsive buildings are not inferior;* they offer positive health benefits and better comfort control.
- *Good design need not cost more;* successful outcomes can be achieved within the traditional budget constraints. Although even better ones can be achieved if the benefits of reduced recurrent costs are linked to the initial capital costs.
- *Technology exists to both design and implement*; the significant advancements in assessment tools now allow designers to risk manage their designs and achieve a truly integrated and environmentally successful solution.

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