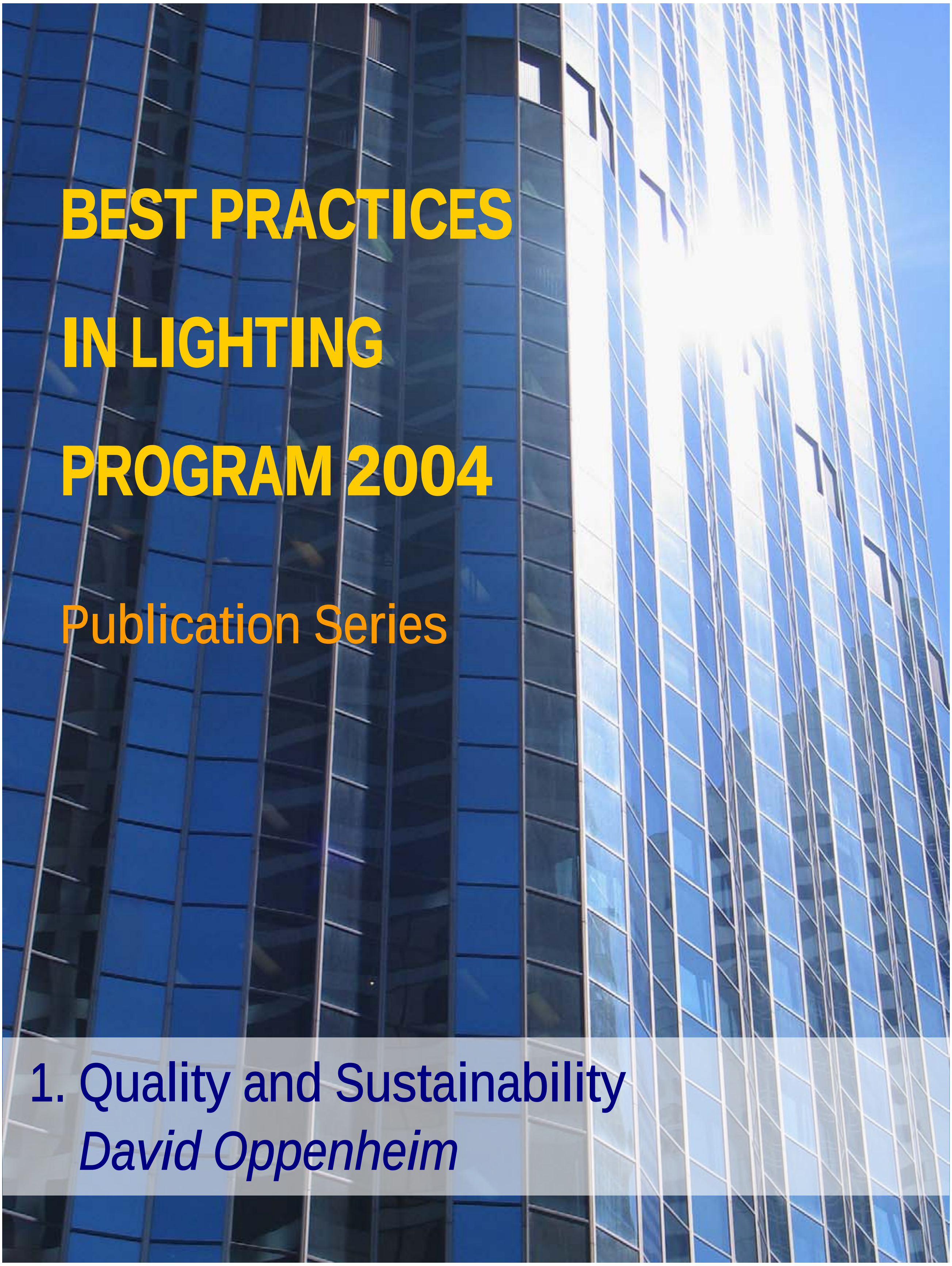

BEST PRACTICES IN LIGHTING PROGRAM 2004

Publication Series

1. Quality and Sustainability

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THE AUSTRALIAN COUNCIL OF BUILDING DESIGN PROFESSIONS LTD

BEST PRACTICE IN LIGHTING - QUALITY AND SUSTAINABILITY

David Oppenheim, Director, SBE

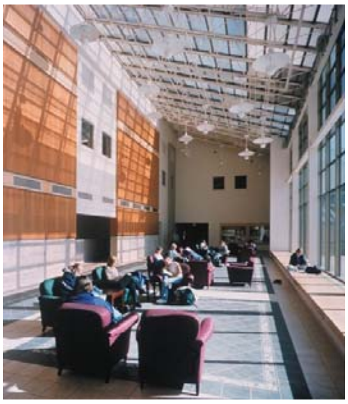
Introduction

This paper has been written to show firstly where Lighting Design fits into the overall sustainability context, and secondly to show how Lighting Design forms an integral part of that sustainable context. It does not detail design techniques nor material selections. Rather, it provides a framework that building design professionals can use to better inform themselves when undertaking lighting design. Whilst the information given below has applicability for many typologies, emphasis has been given to office buildings.

This paper is divided into three main sections.

The first section of the paper provides a brief overview of Ecologically Sustainable Development (ESD) and how it relates to the built environment, in order to set the context in which daylight and lighting design sits. ESD is described using twelve headings. ESD is taken to be the response by designers of the built environment to the issue of sustainability.

The second section of the paper takes various parts of these twelve elements and discusses how daylight and lighting design can improve the ESD outcome of a built environment project. Only by taking this orderly approach of evaluating lighting against the twelve ESD descriptors can a sharper picture be drawn on how lighting fits into sustainability. As can be seen, it is not just about lux levels and energy efficiency. Issues such as architectural planning, indoor environment quality, and on-going maintenance are important.



The third section of the paper provides two case studies where daylight has been an important design driver.

None of the lighting design techniques or technologies noted below are described in detail, since more specific and particular information on each topic is available elsewhere. References have been provided in this paper where more detailed information can be found. As noted above, this paper has been produced as an overview, setting lighting design in context within sustainability.

1. Ecologically Sustainable Development (ESD)

The World Commission on Environment and Development (WCED) in their Report *Our Common Future* (also known as The Brundtland Report) defines Sustainable Development as development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

There are many different ways of interpreting this definition and putting descriptors on it. This paper suggests that twelve topics can be used to describe ESD in relation to the built environment. These are set out below with a brief description against each.

1.1 Pre design issues
This issue deals with the ESD aspirations of the client, the degree of collaboration within the project team, auditing, target setting, the methodologies to used, and Triple Bottom Line (TBL) assessment.

1.2 Site planning issues
This issue deals with the broad brush approach that either lays the building onto the site, or examines the issue of redevelopment / extension of an existing facility. Broad issues such as the ecological value of the site, solar access, solar overshadowing, external night-time light pollution, and natural ventilation are addressed.

1.3 Architectural planning issues
This issue deals with a more detailed conceptual design of the building. Here issues such as openings design for daylight and views, window shading, ventilation paths, thermal mass, and colour schemes etc are considered. It is the first of the four main ESD issues that has relevance to lighting.

1.4 Energy issues
This issue deals with ways to minimise energy use and consequential greenhouse gas emissions. Design proposals are set against previously established targets, and then evaluated. Issues such as energy efficiency for HVAC and lighting systems, lighting zoning, lighting power densities, controls, sub-metering, domestic hot water provision, small power, lifts, refrigerants used, and legionnaires disease are covered in this section. It is the second of the four main ESD issues that has relevance to lighting.

1.5 Water issues
This issue deals with the water used in the operation of the building, and more recently, the embodied water used in the materials selected for use in the building (EDG Note GEN 58 Embodied Water of Construction). It also covers landscape water use, reduction of water discharged to stormwater and sewer mains, and the pollution levels of any water outfall.

1.6 Waste issues
This issues deals with techniques that minimise, and ideally eliminate, waste from the manufacturing process (this is rarely

under the control of the building design professional), construction process (including demolition if relevant), as well as waste generated in operating the facility.

1.7 Material selection issues

This issue deals with the materials selected for use in the building. This is a complex area, and a quickly changing one, as manufacturers respond to emerging demands from clients and designers for more “ESD sensitive” materials. It deals with embodied energy, durability, sustainability of sources, recyclability, reuse, PVC content, etc. It also deals with emissions from materials, such as volatile organic compounds (VOCs), and involves assessment of Ozone Depletion Potential (ODP) and Global Warming Potential (GWP).

1.8 Indoor environment quality issues

This issue deals with the control by individuals of their environment, ventilation rates, quality of the lit environment, daylight, glare, views, thermal comfort, noise, and indoor air pollutants. It is the third of the four main ESD issues that has relevance to lighting.

1.9 Landscape issues

This issue deals with biodiversity, plant selection, water use, and the ability of the landscape to effect and improve the ESD performance of the building.

1.10 Transport issues

This issue deals with the impact of transporting people, goods and services to and from the built facility. It includes such issues as bicycle use, car pooling, smart travel, public transport, fuel substitution, *Green Fleet*, etc.

1.11 Social and community issues

This issue deals with the responsibility that facility designers have with the community at large. It covers issues such as intergenerational equity, human rights, labour practices, decency of work, societal impacts, product responsibility, public art, community meeting places, public change rooms, and provision of a safe and healthy inside and outside environment, including the lit environment.

1.12 On-going management issues

This issue deals with techniques that will continue to deliver the desired ESD performance outcomes. It covers such issues as commissioning, handover, user guides, and on-going maintenance. It is the fourth of the four main ESD issues that has relevance to lighting.

2. Lighting and sustainable practice

How then can lighting design improve the ESD outcomes of a project? This second part of the paper discusses this proposition using the same twelve headings detailed above, and shows how lighting design sits in the ESD context.

2.1 Pre design issues

Client's requirements and aspirations The first action required is to ascertain the client's requirements and aspirations. This will include the light levels required, or if these cannot be specified or there is no particular requirement, then the required Australian Standards should be identified and then applied. It will also include the extent of local occupant control required, the degree of future rezoning and re-lamping envisaged, and the out of hours access lighting strategy to be implemented.

Participatory Approach to Design The methodology used for the project needs to be set at this stage. A participatory approach is recommended where the whole project team is engaged in the design process in a collaborative manner (EDG Note DES1 – A Participatory Approach to Energy Efficient Design).

Link between lighting and sustainable practices The link between lighting design and sustainable practices needs to be made at this stage with the client and the project team. It will, of course, be made as part of an overall ESD package rather than as an individual item. It is important that the client accept this notion, otherwise the option assessments undertaken at a later stage will be difficult.

Auditing and target setting It is often beneficial to audits the client's existing premises (if there are any) to determine the energy used for lighting, the light levels that exist, and the relevant aspects of the indoor environment quality such as glare. This information, combined with the information developed in the client's brief, will permit the setting of targets.

TBL assessment The methodology used in assessing ESD opportunities needs to be set at this stage. Whole of life assessments are preferred, and a TBL basis is preferred. A TBL assessment involves economic, environmental and social outcomes. As it becomes more widespread, the notion of assessing design options only under one criteria, economic, is seen as limiting.

2.2 Site planning issues

The approach to site planning issues with respect to daylight is threefold.

Firstly, it is important to ensure that there is sufficient sky viewable from all windows and skylights. Secondly, it is important to ensure that the proposed development does not overshadow other sites and deny them their access to daylight. Thirdly, it is important to minimise, or eliminate, external night-time light pollution. This means that all external lighting should be directed downwards in order to strike a building surface and / or ground surface.

2.3 Architectural planning issues (first main ESD issue)

This is the first of the four main ESD issues involved in best practice daylight design. Other papers on daylight describe in detail the ways to undertake energy efficient daylight and lighting design in order to provide a delightful internal environment. Suffice to say that window sizing, window location, window shading and internal colour schemes are vital.

It is also important to be aware of the tumble down effect, and interdependence, between building fabric and building services design. Initial capital cost can often be reduced by designing a better building fabric that will reduce the size of the lighting system and HVAC system required as a result. With respect to lighting, it is interesting to note that in quite a few existing commercial buildings, the heat regain to the return air path from light fittings, and lighting in general, is factored into the building's control system. This system may control the air conditioning to a number of floors, so that if the heat load from the lighting (which is effectively a "given" in the control algorithms) on one floor changes because a tenant wants to do the right thing and utilise daylight and introduce energy efficient lighting, this can have deleteriously effects on the air conditioning control on all the interconnected floors and possibly lead to an increase in air conditioning energy consumption.

2.4 Energy issues (second main ESD issue)

This is the second of the four main ESD issues involved in best practice daylight design. Once again, other papers on daylight describe in detail the ways to undertake energy efficient daylight and lighting design that provides a delightful internal environment. Suffice to say that the opportunities needed to be addressed include energy efficiency for lighting systems, lighting zoning, lighting power densities, lighting ballasts, sub-metering, and lighting controls. An appreciation of the flow-on effect is once again vital. Poor lighting design will also increase the energy required to cool the building, and whilst it appreciated that this would bring marginal decreases in heating load, it is noted that using inefficient lighting is not a good way to heat a building.

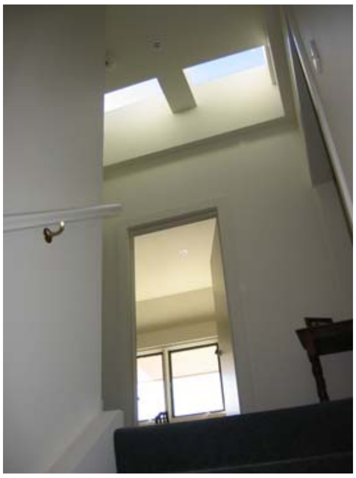
2.5 Water issues

If water based cooling towers are used, another ESD impact could be the increased water usage caused by increased cooling loads resulting from inefficient lighting design as noted above. It is acknowledged, however, that this would be a minor effect, and that more water is wasted in cooling towers through bad maintenance than through energy inefficient lighting.

2.6 Waste issues

Four issues need to be addressed: firstly, the waste generated from the manufacture of fittings (which is often beyond the control of the building design professional); secondly, the potential waste generated from the incorrect selection of fittings that are not durable or which do not have a long life and hence require replacement more often; thirdly, the waste generated during the installation of fittings; and fourthly, the waste generated in the on-going maintenance of the system. These last two items are best addressed in a Construction Waste Minimisation program for the whole project. If such a program is not envisaged for the project, this issue for light fittings may be used as a prompt for the consideration of one.

2.7 Material selection issues



Material selection is often ignored in an ESD appreciation of daylight design. The material selection is a complex task, and information can be found in the references below (including EDG Note DES 35 - Building Material Selection). Issues such as embodied energy, durability, sustainability of sources, recyclability, reuse, PVC content, and emissions from materials, such as VOCs, need to be considered.

2.8 Indoor environment quality issues (third main ESD issue)

This is the third of the four main ESD issues involved in best practice daylight design. There are many elements to consider, such as control by individuals of their environment, the quality of the lit environment, daylight levels, glare, views, and the resultant productivity and retail sales gains. Issues of the level and quality of the light provided are dealt with in other EDG Notes.

Individual control has been shown to increase productivity (www.lrc.rpi.edu/daylightdividends). It is noted, however, that the Green Star assessment method (www.gbcaus.org) gives credits for designs that allow for individual user control of air supply rates to each workspace, but no credit for individual control of lighting.

Recently, much emphasis has been placed on productivity and retail sales increases resulting from improvements in the internal environment quality. In the retail sector, it has been shown that the value of the energy savings from the daylighting is far overshadowed by the value of the predicted increase in sales due to daylighting (Heschong Mahone Group, Oct 2003).

Better access to views has also been shown to produce improved performance in Call Centres. Office workers were found to perform 10% to 25% better on tests of mental function and memory recall when they had the best possible view versus those with no view. For students, findings clearly support the theory that interesting views to outside enhance, rather than detract, from student learning (Heschong Mahone Group, Oct 2003).

Distance from the external windows has been linked to productivity. It is noted that the Green Star assessment method awards credits to floor plate areas that are within 8 metres of an external window.

2.9 Landscape issues

There is a variety of opinions as to whether landscape elements should be formally considered in the evaluation of energy and lighting designs. It is noted that the Australian Building Greenhouse Rating (ABGR) tool (www.abgr.com.au), in its computer evaluations, acknowledges that trees will have an effect on performance.

The potential positive and negative effects of landscaping elements should be considered: for example, positively, to provide shade in summer; and negatively, when blocking out of daylight that was once provided through a window. The effects of such landscaping measures need to be subjected to risk analysis, to ensure that if the landscaping element changes (ie, a tree grows up, or, a tree is cut down), the effect is not unmanageable or unwanted.

2.10 Transport issues

There are no direct issues regarding transport. There are, of course, indirect issues involving the transport required to supply, maintain and dispose the facility. Such an analysis is beyond the scope of this paper.

2.11 Social and community issues

The obvious issue here is the provision of public safety. Lighting design should consider adequate and appropriate external lighting (e.g. lighting near entrance ways and in areas that are not covered by 'natural' surveillance means such as rear entranceways), lighting controls, and elimination of external night-time light pollution.

2.12 On-going management issues (fourth main ESD issue)

This is the fourth of the four main ESD issues involved in best practice daylight design. The importance of on-going commissioning is vital. Studies of various buildings have shown that good housekeeping at minimal cost can achieve great energy savings. Issues include hours of operation, equipment failure, system drift, design life, light fitting recycling, handover manuals, user guides, and regular and effective on-going maintenance driven by a regular monitoring schedule.

Hours of operation

Many lighting control systems are commissioned to control lights on and off to an assumed occupancy pattern and this is never checked. Automation provides the opportunity to ensure efficiency on a broad scale, but if the automation goes wrong, there is a chance that energy will be wasted on a broad scale. The levels of occupancy at which the lighting goes from "out of hours" control to "in hours" and back to " out of hours" are important. Ideally the "in hours" operation is a short as possible, but this has to be managed against occupant requirements and perceptions. This needs to be audited at least annually.

Equipment failure

Occupancy detectors, like all things, fail eventually. Cheap occupancy detectors fail sooner. A lot of modern lighting control systems feature occupancy detectors for individual office lighting control, or control of lighting in small spaces such as store rooms etc. When these devices fail they usually fail to "on", or they stay on longer than they should. Audits of these devices are done infrequently, but where audits are done, failure rates of up to 30% within 2-3 years of installation are not uncommon.

System drift

Modern lighting control systems relies on electronics to manage time schedules, lighting levels, etc against changing daylight conditions or deteriorating luminaire output. These devices themselves drift or deteriorate over time and should be checked regularly.

Design life

The accessibility of luminaries for maintenance is sometimes an issue. External lighting or lighting in atria can be difficult and expensive to access both in terms of money and in environmental terms (travel, hire of cherry pickers, scaffolds etc). In these instances it is important to consider the longevity of the light source and the implications of that against energy efficiency and other ESD issues.

Recycling of lamps

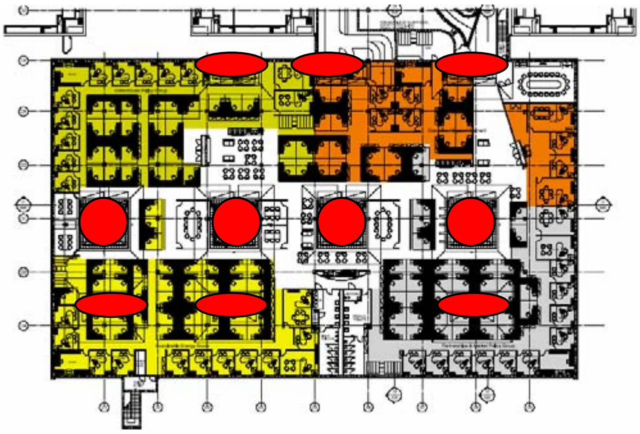
Collection and recycling of lamps is available in Australia. For example, Chemsal has principle depots and administration departments in Sydney and Melbourne, and this service can be provided in other States and Territories. Chemsal are currently treating approximately one million fluorescent tubes per year, plus HID lamps.

3. Case studies

The following two pages provide case studies for two buildings that had addressed the issue of daylight as a fundamental design driver. These case studies are the new AGO headquarters in Canberra, and the Park Ridge Primary School, in Melbourne.

3.1 New AGO Offices, Canberra

Location: **John Gorton Building, Parkes, Canberra**
Architects: **Daryl Jackson Alistair Swayn**



Courtyards penetrating underground office spaces.

Summary

Located in a basement beneath an existing ground level carpark on the site of the John Gorton Building, this innovative project entails a refurbishment of the basement into new office spaces, providing daylight and visual access to the outside environment via a series of courtyards and skylights. The sub-terrain nature of this project highlights the necessity of a well-considered approach to natural and artificial lighting strategies.

Daylighting

Four courtyards and six skylights are distributed strategically across the building plan, bringing natural light into the space and significantly reducing the demand for artificial lighting. Light shelves assist in reflecting daylight further into the building, diffusing concentrated lux levels occuring around the courtyards and skylights to provide more uniform lighting conditions. Daylight sensors adjust artificial lighting levels according to available natural light, thus minimising energy use.

External & internal views of light shelves for courtyard.

Artificial lighting

Suspended luminaries consist of three energy efficient T5 fluorescent lamps with dimmable ballasts. Two lamps provide upward ambient lighting, and the remaining lamp provides downward task lighting. Each component is individually controlled, to coordinate with daylight conditions from the skylights and courtyards and optimise energy savings.

Suspended luminaires, and external screens on courtyard windows.

Lighting control

A Clipsal 'C' Bus system controls lighting via a series of lighting level sensors at ceiling and desk top height, movement sensors and local area controls. All artificial lighting responds to the levels of natural light within the occupied space. Local switches control designated work areas, to provide flexibility in the zoning and use of lighting. Movement sensors are incorporated into many aspects of the design, including the program for the beginning and end of the day, and occasionally occupied spaces such as bathrooms.

Challenges

A change in the landscaping treatment to the courtyards created a temporary glare problem off the light coloured paving surface. This is being addressed by the installation of internal blinds on the north sides of the courtyard.

External and internal views of skylight penetrations.

3.2 Park Ridge Primary School, Melbourne

Location: **Rowville, Melbourne, Vic**
Architects: **Taylor Oppenheim Architects**

Summary

The design for Park Ridge Primary School, a government school for a maximum of 700 students, exploits passive solar design strategies to minimise the need for electrical lighting and capitalise on natural light. The temperate climate and relatively sunny conditions are ideal for such a design, balancing temperature control with the need for sufficient lighting within classroom spaces.

Daylighting

The single storey design allows for roof penetration to maximise classroom daylight levels, in the form of an externally shaded skylight running the length of the room from east to west. An inverted 'V' shaped deflector beneath the skylight bounces light onto adjacent ceiling surfaces, distributing even lighting through the classroom. Windows, predominantly located to the north, are shaded with steel mesh screens to allow daylight to enter while preventing direct sunlight and associated glare.

Artificial lighting

Control for electric lighting is switch operated, a simple manual 'on' and time-programmed 'off' system. This technique increases occupant awareness in regard to lighting use, and avoids unnecessary energy consumption in unoccupied rooms.

Temperature control

Skylight shading is positioned to prevent direct solar access for ten months of the year but allow solar gain for the remaining two, in the coldest winter period, to take advantage of passive solar heating. Moderate use of thermally massive building materials affords flexibility in temperature control during extremes of summer heat and winter cold.

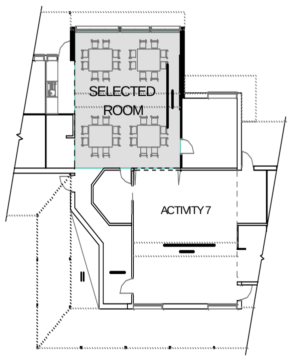
Challenges

This building was monitored for one year as a case study for the International Energy Agency's Task 21 on Daylight in Building. The process provided evidence to support the strength of the overall strategies, while exposing some occupant concerns, including light switch marking and zoning control, and dust collection on the inverted light deflectors. This constructive feedback provides valuable lessons for future applications.

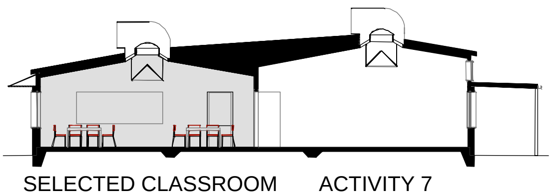
View from northeast, showing skylight and window shading.

External view of skylight with steel mesh shading.

Internal view of classroom with skylight.



Plan showing north-oriented classroom and east-west skylight.



Section showing central skylights and window shading.

4. Conclusions

The following environmental issues and their principal impacts are noted below.

- ESD descriptors for the built environment can be summarised under twelve headings
- Lighting design options should be assessed using Triple Bottom Line (TBL) accounting.

The four main ESD impacts concerning lighting are:

- The principal ESD impact of lighting design is greenhouse gas emission arising from the use of electricity to provide electric lighting
- Good architectural planning is required to maximise the benefits of daylighting
- Improved quality of the lit environment will produce benefits (productivity, increased sales, etc)
- On-going maintenance programs should include recycling of equipment (ie failed / replaced lamps, transformers etc)

Other ESD issues include the following:

- If water based cooling towers are used, another minimal ESD impact is high water usage caused by increased cooling loads resulting from inefficient lighting design
- Waste minimisation of wires, etc can be achieved by minimising size of the load, introducing power correction equipment
- Material selection of fittings and wiring is important (ie eliminate PVC)
- Landscaping elements need to be risk assessed to ensure on-going benefit is possible.

The following ESD strategies should be used by the project team.

- Maximise daylight usage but eliminate glare and overheating consequences
- Use energy efficient lamps, luminaires, ballasts, controls, BMS
- Ensure lighting system has minimal overall life cycle cost
- Select equipment that is made from ESD acceptable materials

References and Further Reading

Web sites

www.lrc.rpi.edu/daylightDividends
This site is maintained by the Rensellaer Polytechnic Institute in Troy, USA. It has research and advice for building owners, architects, engineers, and has a series of case studies.

www.abgr.com.au
This is the official site of the Australian Building Greenhouse Rating scheme.

www.gbcaus.org
This is the official web site of the Green Building Council of Australia that has developed and maintains the Green Star scheme.

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BDP EDGe notes

GEN 1 – RAIA Environment Policy
GEN 26 – AILA Environment Policies
GEN 27 – Policy on Sustainability - The Institute of Engineers, Australia
GEN 28 – RAPI ESD Policy
GEN 24 – Light pollution
GEN 58 – Embodied Water of Construction
TEC 9 – Emerging Technologies in Lighting
DES 1 – A Participatory Approach to Energy Efficient Design
DES 6 – Natural lighting in Buildings
DES 7 – Energy Efficient Artificial Lighting
DES 35 – Building material selection

Biography

David Oppenheim is an architect and ESD consultant with over 30 years experience in energy efficient and environmental design for the built environment. Between 1980 and 2001, he was a director of the architectural firm Taylor Oppenheim Architects, and from 2001 onwards has been director of the Melbourne based ESD consultancy of Sustainable Built Environments (SBE). Further details can be found on the web site www.sbe.com.au