BLINDS DOWN UNDER – A COMPARATIVE ANALYSIS OF SHADING SYSTEMS FOR SUSTAINABLE BUILDING REFURBISHMENTS

Christoph Begert[1], Eckhart Hertzsch[2]
[1]Sustainable Built Environments (SBE), Sydney, Australia
[2]Architecture, Building and Planning, Melbourne University, Melbourne, Australia

ABSTRACT

This research investigates glare control strategies in reference to operational energy consumption and productivity for sustainable upgrades of existing buildings in two very different climate zones. This way the climate sensitivity of glare prevention solutions including the impact on operational energy consumption can be shown. Operating control strategies for various internal blind configurations for a tight renovation budget are tested for three different desk positions and compared with the impact of the Australian "blinds-down approach".

Different financial scenarios have been analysed, including productivity increases. The savings due to productivity are compared to the cost reduction due to the achieved operational energy savings and to capital expenditure for the initial costs for the buildings in Melbourne and Darwin.

INTRODUCTION

Increasing concerns about climate change demand more stringent energy performance requirements for buildings. Balancing these requirements with other design objectives, such as good indoor environment quality, becomes increasingly challenging. This is specially the case for refurbishments of buildings when the budget is sized to one isolated problem, thus hardly allowing the optimization of follow on effects.

This research shows an integrated design approach on strategies to optimize visual comfort and its benefits that vary in relation to climatic zones. The analysis has been undertaken for two very different locations in Australia, Melbourne and Darwin. Melbourne is located in the south of Australia and characterised by a cold-tempered climate. The climate zone is typically classified as a heating climate, however heat waves in summer with temperatures around 40°C are not uncommon for a short period of time. Darwin is located in the tropical northern parts of Australia. The year is divided into a dry season, from April to October, and a wet season lasting from November to March.

The following table outlines the differences of heating and cooling degrees days (HDD and CDD) in the two cities.

Table 1 HDD and CDD

Melbourne	
HDD (16°C)	1,383
CDD (22°C)	132
Darwin	
HDD (16°C)	0
CDD (22°C)	2,028

HDD: Heating Degree Days
CDD: Cooling Degree Days

METHODOLOGY

This research intends to analyse financial scenarios of blind solutions in buildings in two very difference climate zones that reduce the operational energy consumption, create an optimised visual comfort herewith positively impacting on the occupants' productivity.

Thus research questions are:

a) What impact do the two climate zones in Australia have on glare risk for different seating scenarios?
b) What impact has the blind control on glare prevention and operational energy consumption?
c) How do productivity increases that might be gained from responsive blinds relate to the overall Internal Rate of Return (IRR)?

In order to find answers to the above questions daylight and energy consumption have been simulated for a typical office configuration. The basic geometry of the entire office building is shown in figure 1. Each floor consists of six 10m x 10m units with a full length window strip using a light weight construction. This setting allows to analyse a typical perimeter zone that is connected to a larger internal area. The windowsill is 1m above ground and it has a height of 1.5m. The glazed facades face north and south.

The analysed unit is facing north, the sun exposed orientation in the southern hemisphere. In order to ensure correct boundary conditions for the thermal modelling, the office units surrounding the analysed unit have been conditioned. The arrow in figure 1 points to the office unit for which the risk of glare and operational energy has been calculated for working hours from 8am to 6pm.

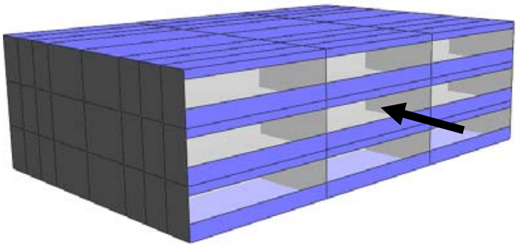

Figure 1 Basic Geometry of the Energy Model

Glare risk was analysed by using the lighting simulation program Radiance to evaluate glare for the period of the brightest sky. Glare statistics for the entire year are obtained through Daysim; a validated daylighting analysis software that can evaluate various daylight metrics as well as the *Daylight Glare Probability* (Wienhold 2006) on an annual basis. It is based on Radiance and uses additional programs developed by Christoph Reinhart (2001).

To determine the impact of blind solutions on glare and operational energy consumption IES Virtual Environment (VE) was used. VE is an integrated dynamic simulation package, which complies with ASHRAE Standard 140 (BESTEST). VE also provides a link to Radiance. A set of Radiance sensors were placed in the analysis to be able to determine lighting energy savings. The results of these sensors were also used to determine how often glare could be problematic.

Glare analysis

Three different seating arrangements have been analysed: parallel to the window, sitting at a 45° angle as well as perpendicular to the facade, as illustrated in Figure 2.

The model has been checked for glare during a day in March, June and December at 12pm. The hour of the day has been chosen to test for glare when the sky in view is the brightest. The radiance settings are shown in Table 2.

The combined visible light transmittance (VLT) of the window/blind system has been applied that varies from 0.024 to 0.16; the latter representing, for example, a blind with a VLT of 20% on a glass with a VLT of 80%.

Figure 2 The three different seating arrangements

Table 2 Radiance settings

	General	High Quality	Daysim
-ps	4	2	-
-pt	0.05	0.25	-
-pj	0.9	1	-
-dj	0.7	0.9	0
-ds	0.15	0.05	0.2
-dt	0.05	0.03	-
-dc	0.5	0.75	-
-dr	3	5	2
-dp	512	1024	512
-sj	0.7	1	1
-st	0.15	0.1	0.15
-ab	2	5	5
-aa	0.15	0.08	0.1
-ar	128	256	300
-ad	512	1024	1000
-as	256	512	20
-lr	8	12	6
-lw	0.002	0.001	-

Further settings are:

- The ambient values are set between 0.1 and 0.89, in order to test the impact of internal lighting on glare from the outside.
- A fisheye view has been used, covering 180° by 180°.
- The sky has been set to clear and included the sun.

Glare has been determined using the *Guth Visual Comfort Prediction* (Guth VCP) index. This relatively simple metric estimates the number of people satisfied as a percentage, i.e. a Guth VCP of 80 means that 80% of the occupants would be satisfied. To achieve further accuracy for the critical scenarios, the radiance simulation was repeated using the higher quality settings shown above.

To estimate how often glare might be a problem Daysim and the VE were used. The *Daylight Glare Probability* in Darwin and Melbourne was determined with Daysim for VLTs of 0.08 and 0.16. The radiance settings for the Daysim simulation were in accordance with preset values.

Three radiance sensors have been placed at the midst of the window, at a distance of 1m (sensor 1), 3m (sensor 2), and 5m (sensor 3).

High sensor readings indicate either a particular bright sky or direct sunlight penetration in this particular spot. Either has the potential to cause glare directly or by reflections on internal surfaces.

It is assumed that there is a risk of glare whenever the illuminance reading of any of the sensors is above 2000 lux. For readings greater 5000 lux, the risk of glare is deemed to be very high. The range has been set rather large to make allowance for the limited number of sensors.

Analysis of operational energy

The office room has been split in three parallel 2m deep perimeter zones and one 4m deep internal zone.

The building envelope has been based on the Building Code of Australia 2008 which allowed a lower thermal performance compared to the current version. The ribbon window system contains of single glazed elements, with the VLT of the glass varying between 40%, 60% and 80%. The shading coefficient (SC) has been adapted by changing the transmittance of the windowpane.

Table 3 shows the most relevant properties for the analysed zone of the building envelope.

Table 3 Thermal Properties of the façade

Facade Element	Thermal Properties
U-Value wall	0.56 W/m^2.K (= R1.8 m^2.K/W)
U-Value glass	4.8 W/m^2.K (ASHRAE)
Shading Coeff. glass/blind	0.8 / 0.68 / 0.48

The energy base case assumes no blinds. All other scenarios are using blinds with a shading coefficient of 0.05. The blinds-down scenario is assessed by showing the reduced energy savings due to continuous operation of the lights.

The following scenarios have been analysed:

(1): No blinds, no lighting dimming

(2): Blinds are operated, no light dimming; this determines the effect of blinds on heating and cooling

(3): Blinds are operated and lights are dimmed when suitable; this scenario allows analysing the effect of reduced internal heat gains by lighting dimming

The blinds are open whenever the reading from sensor 2 is between 500 lux and 2000 lux, i.e. when sufficient daylight is available without any risk of glare. The lower lux level has been used by e.g. Reinhart 2001 and is the recommended lighting level in various lighting standards (e.g. DIN EN 12464). The higher lux level is in accordance with the upper level used for the *Useful Daylight Autonomy,* proposed by Mardaljevic and Nabil in 2005.

Where the models included light dimming, the lighting in the three perimeter zones is turned off when the blinds are open. The lighting in the internal zone remains on.

The office is conditioned with a standard split system. The as-delivered Coefficient of Performance (COP) has been varied from 1.5 to 3. It is noted that an as-delivered COP of 3 is deemed to be rather high for an existing office. Energy savings for this scenario would be therefore relatively small.

As-delivered means that the COP includes all energy that is required to meet the call for heating and cooling in the zone (fans, heat pumps, motors, etc.). While this is a simplification, it allows to post-process the data more easily and to adapt the results for a specific HVAC solution.

All operational profiles, such as occupancy and internal loads as well as lighting, are in accordance with the National Australian Building Rating System (NABERS) computer protocols. This tool rates the performance of commercial buildings. It is the accepted Australian standard and forms the bases for Australia's more holistic Green Star rating tool (GBCA 2008).

The NABERS protocol assumes installed lighting power to be 11 W/m; this value is rather on the lower end of what could be expected in existing older buildings. Therefore the modelled direct and indirect (cooling demand) energy savings due to the blinds and daylight control is fairly conservative.

The economic model

The financial viability analysis of the calculated scenarios and their impact is based on the more precise Internal Rate of Return (IRR) rather than a mere payback period. The calculation includes factors such as expenditure for blinds, electricity costs and productivity.

Costs for blinds, sensors and labour are based on Rawlinson 2010. Motor costs have been determined by a short survey of suppliers and are assumed to be \$800 per unit. At a blind width of 2m, five motors would be required. The time for installing and calibrating the blinds and daylight sensors was considered to be around 15 person-hours.

Table 4 Costs calculations of the blinds

Item	Number	Costs	Total
Blinds	15 m^2	\$295/m^2	\$4,425
Motor	5	\$800/unit	\$4,000
Sensors	1	\$200/unit	\$200
Labour	15 hours	\$63/h	\$945
Total			\$9,570
Total incl. further contingencies			\$10,000

Based on the 100m^2 wide floor plan, the total costs are \$95.70 per m^2. To accommodate potential price differences between both cities, further 4.5% have been added as contingencies and the total cost is assumed to be \$100 per m^2.

Electricity costs have assumed to be 15cts/kWh for Darwin (PowerWater 2011) and 20 cts/kWh for Melbourne (Origin Energy 2011).

The economic model also includes a factor for enhanced productivity. It should be noted that 'productivity' within the scope of this research includes effects, such as reduced absenteeism, improved health as well as employee effectiveness. Previous studies showed that window size, proximity to the window, external views as well as glare protection are linked to better occupant comfort and increased productivity (Hedge 2000, Leather et al. 1998, Mallory-Hill et al. 2004). Improved daylighting in hospitals is known to impact on the amount of medication required and recovery rates (Ulrich 1991, Verderber et al. 1988). Heshong et al. (2002) showed that students in classrooms perform certain tasks better when the quality of daylight is high. The exact effect of blinds and IEQ on productivity in general however is uncertain. Kats (2003) compared ten studies on the link between productivity and the lighting quality. The estimated impact ranges from 2.3% - 15%. Fisk (2002) estimates that the potential for direct productivity gains for optimising thermal and visual performance is between 0.5% and 5%. As discussed in the economic analysis below, a productivity increase of 0%, 1%, 2%, 3% and 4% respectively has been included in the calculation.

Employee costs vary widely and strongly depend on the nature of the business. Service businesses that fully depend on intellectual property generated by the employees (e.g. IT, engineering or architecture offices) might well have employee costs higher than \$4,000 per m^2; e.g. Tregeagle, et.al. (2011), Australian Bureau of Statistics (2010). To follow the conservative approach costs for employees have been calculated for both, \$1,500 and \$4,000 per m^2.

RESULTS

Risk of glare

At 500 lux internally, the results indicate that a VLT of 0.16 would be sufficient to avoid glare from spring to autumn in all scenarios. The Guth VCP has been at or close to 100, which means that everyone should be satisfied with the visual comfort.

Glare occurred in Melbourne during winter due to the low standing sun and internal reflections (Figure 3). This resulted in a Guth VCP of zero. Lowering the VLT from 0.16 to 0.04 achieved a nearly optimal Guth VCP.

Figure 3 Melbourne Office (June, 12pm) - VLT = 0.08;

Being located much closer to the equator, glare is easier to manage in Darwin. A VLT of 0.16 provided sufficient glare protection even during winter. In comparison to Darwin, with lower internal light levels some minor glare occurred in Melbourne during spring/autumn due to increased contrast when using a VLT of 0.16. This glare could be prevented by using a VLT of 0.08.

Rotating the desk and view by 45° and 90° respectively strongly influenced the risk of glare. Using no blinds during December in Melbourne resulted in a Guth VCP of 42.6 when sitting parallel to the window. This increased to 53.64 for the 45° seating arrangement and to 82.91 when sitting perpendicular to the window. The results for Darwin showed a similar trend. These comfort values were obtained for the centre of the view (i.e. 0° angle). They decline for angles towards the window.

Table 5 shows the readings from the sensors of the energy model to indicate how often glare might occur. The results obtained by the DAYSIM model show that glare is problematic for approximately 40% in Melbourne and 57% in Darwin. The results therefore illustrate that glare potentially occurs more often in Darwin than in Melbourne. The intensity of glare however is higher in Melbourne.

Table 5 Sensor readings

Darwin lux	>2000	>3000	>4000	>5000
Sensor 1	73.3%	54.6%	38.0%	31.0%
Sensor 2	0.0%	0.0%	0.0%	0.0%
Sensor 3	0.0%	0.0%	0.0%	0.0%
Melbourne lux	>2000	>3000	>4000	>5000
Sensor 1	58.1%	39.7%	28.5%	24.3%
Sensor 2	4.9%	3.3%	2.0%	1.4%
Sensor 3	0.0%	0.0%	0.0%	0.0%

Impact on operational energy consumption

The obtained results have been validated using the benchmarks set by the Property Council 2007 for Best Practice Existing Buildings and are shown in the tables 6 and 7 for a COP of 3 and the scenarios mentioned above.

Compared to the data of the Property Council, the results for lighting energy in the no dimming scenario were 11% higher. Cooling energy in Melbourne was 33 % higher and 24% in Darwin. This increase seems reasonable for a perimeter zone. Heating in Melbourne was 35% below the benchmark of the Property Council.

The results show that blinds can significantly reduce the demand for cooling in both Melbourne and Darwin. The savings range from 30% - 68% in Melbourne and from 6% - 19% in Darwin, for the chosen glass type.

The chosen profile for the operation of blinds also increases the heating demand in Melbourne (4% - 10%), however the overall energy consumption for heating and cooling is significantly reduced.

Interestingly, the results seem to indicate that blinds on a clear window lead to larger absolute savings for the cooling energy. A darker, and thus hotter, window in combination with the blinds seem to have an effect similar to a solar air heater.

While notable, the effect for the analysis in the scope of this paper is small enough to be ignored and might also be an artefact due to the simplified shading coefficient adaptation in combination with the heat transfer method used by VE.

Table 6 Melbourne Energy Results

Melbourne (kWh/m²)	No blinds; no lighting dimming	Blinds operated; no light dimming	Blinds operated; lights dimmed
Window VLT: 80%			
Cooling	18.2	6.7	5.9
Reduction		63%	68%
Heating	5.4	5.8	6.4
Reduction		-8%	-18%
Lighting	43.3	43.3	25.9
Reduction		0%	40%
Total	66.9	55.8	38.2
Reduction		17%	43%
Window VLT: 60%			
Cooling	15.5	7.8	7.0
Reduction		49%	55%
Heating	5.5	5.8	6.3
Reduction		-5%	-14%
Lighting	43.3	43.3	25.8
Reduction		0%	40%
Total	64.3	56.9	39.1
Reduction		12%	39%
Window VLT: 40%			
Cooling	11.3	8.8	7.9
Reduction		22%	30%
Heating	5.7	5.8	6.3
Reduction		-1%	-10%
Lighting	43.3	43.3	26.1
Reduction		0%	40%
Total	60.3	57.9	40.3
Reduction		4%	33%
VLT: Visual Light Transmittance			

Economic Analysis

The potential cost savings due to reduced energy consumption at a rate of 15 ct/kWh equate to \$5.7 - \$8.0 per m² for Melbourne for a COP of 3.0 and 1.5 respectively. For Darwin the savings are ranging from \$4.8 – \$9.6 per m².

Table 7 Darwin Energy Results

Darwin (kWh/m²)	No blinds; no lighting dimming	Blinds operated; no light dimming	Blinds operated; lights dimmed
Window VLT: 80%			
Cooling	70.2	59.9	56.9
Reduction		15%	19%
Lighting	43.3	43.3	24.5
Reduction		0%	43%
Total	113.3	103.2	81.4
Reduction		9%	28%
Window VLT: 60%			
Cooling	68.1	61.4	58.8
Reduction		9.8%	14%
Lighting	43.3	43.3	26.0
Reduction		0%	40%
Total	111.5	104.7	84.8
Reduction			24%
Window VLT: 40%			
Cooling	63.3	61.9	59.7
Reduction		2%	6%
Lighting	43.3	43.3	27.1
Reduction		0%	37%
Total	107.1	105.2	86.8
Reduction		2%	19%
VLT: Visual Light Transmittance			

Despite the relatively enormous reduction in energy, the financial savings are low compared to potential savings due to improved productivity. The savings based on energy reduction would not be sufficient to generate a positive IRR.

The following tables 8 and 9 illustrate the IRR calculated over five years for different delivery COPs and different improvements to productivity. The financial results in both cities are fairly similar and clearly dominated by productivity increases. We also calculated the IRR for a 1% improvement in productivity, which emphasised the differences due to potential energy savings between Melbourne and Darwin. An employee costs of \$2,000 per m² is required to generate an IRR between 9% and 12% in Melbourne and between 8% and 15% in Darwin depending on the COP. As discussed above, for fully service orientated offices, employee costs may be significantly higher and would consequently produce higher returns.

DISCUSSION

The results indicated that glare occurs potentially more often in Melbourne compared to Darwin. However, glare is easier to manage in Darwin. The required VLT of the blinds can be higher, i.e. generally allowing a better connection to the outside. The results also show that in Darwin, a VLT of 0.16 comfortably provides sufficient protection from glare throughout the year. Such a performance would perform equally well in Melbourne from spring to autumn, but not during the winter months. A VLT of 0.08 is required to enhance comfort during winter. The glare modelling also illustrated that the seating arrangement could improve visual comfort for occupants. This is potentially a no-cost solution however it does not address the source of glare.

The energy analysis showed that blinds linked to daylight sensors could significantly reduce energy consumption in both cities. The blinds successfully reduce the energy for heating and cooling by reducing solar heat gains. The bigger energy savings however are achieved by light dimming. This highlights the importance of motorising the blinds in order to make sure that the lighting savings are maximised. While the relative savings were higher in Melbourne, the blind solution was more effective in Darwin in absolute energy savings.

As shown in table 6 and 7, in Melbourne the absolute operational energy savings of introducing blinds on a clear window (80% VLT) and daylight sensors are 43% equivalent to 28.7 kWh/m^2 savings. The same scenario in Darwin delivered 28% savings which is equivalent to 31.9 kWh/m^2.

For a mixed mode building, these savings are an indication that natural ventilation could be utilised more often for maintaining comfort. Given that natural ventilation is usually regarded as favourable from an IEQ perspective, this would be another benefit that is not quantified within this paper.

The results also indicate that there might be a small effect that blinds potentially generate slightly higher energy savings on clear glazing. The effect however is small and might be a result of the simplified shading coefficient reduction in combination with the unknown algorithm IES VE uses for the heat transfer through and between the window and the blind.

Despite representing a significant reduction in energy, from a financial point of view the savings do not produce any return.

Table 8 IRR Melbourne

For an employee cost of \$1,500 per m^2			
IRR over 5 years versus productivity increase			
COP	2%	3%	4%
1.5	23%	33%	51%
2	22%	32%	50%
2.5	22%	31%	50%
3	21%	31%	49%
For an employee cost of \$4,000 per m^2			
IRR over 5 years versus productivity increase			
COP	2%	3%	4%
1.5	82%	103%	144%
2	81%	102%	143%
2.5	80%	102%	143%
3	80%	101%	143%
IRR: Internal Rate of Return			

Table 9 IRR Darwin

For an employee cost of \$1,500 per m^2			
IRR over 5 years versus productivity increase			
COP	2%	3%	4%
1.5	28%	37%	55%
2	25%	35%	52%
2.5	23%	33%	51%
3	22%	32%	50%
For an employee cost of \$4,000 per m^2			
IRR over 5 years versus productivity increase			
COP	2%	3%	4%
1.5	85%	107%	148%
2	83%	104%	146%
2.5	81%	103%	144%
3	80%	102%	143%
IRR: Internal Rate of Return			

Calculated over a five-year period, even small improvements in productivity however would produce significant returns despite a conservative cost assessment. The reality of this return however depends on a variety of factors starting with split incentives, which is not specifically covered here. The calculation assumed that the effect of improved productivity is constant over the years: employees in our modelled building always perform e.g. 2% better when blinds are present. It is unclear how realistic this is. It could be argued that an adaptive effect takes place and that productivity falls back to business as usual after the initial "honeymoon period" that has been induced by improved comfort (or potentially by the Novelty Effect). Likewise it could be argued that, with a mayor annoyance being removed, productivity further increases over the years. Especially in a business that relies on the intellectual property generated by the employees, the improved productivity might enhance the learning curve and thus lead to higher returns each consecutive year.

Further, it is not known what the 'weighting' of visual comfort is compared to other comfort metrics such as acoustics, thermal comfort or fresh air. More research is required to enable building practitioners to better understand the impact of design decisions on occupant comfort and well-being and how this is connected to productivity.

While all these concerns limit the ability to exactly determine the financial case, this research showed the possible range of financial outcomes. As mentioned previously the follow on effects are often not include in typical cost assessments. However, even when calculating conservative (additional contingencies on costs, low employee costs and low impact on productivity), the financial assessment still shows attractive returns even for a tight renovation budget.

CONCLUSION

This research showed the financial viability of glare protection in a refurbishment scenario. We analysed glare for a generic office building in two very different climate zones in Australia, Melbourne and Darwin. The assessment included an analysis how different seating arrangements influence the risk of glare. Furthermore, the impact of different blind operation on energy consumption has been established. To allow for follow on effects, various potential increases in productivity have been included in the financial assessment.

These results might help to inform occupants and owners to decide whether a refurbishment should be undertaken and shows how otherwise financially unattractive energy efficiency measures can become favourable when user comfort is taken into account.

Sustainable buildings must provide enhanced comfort without using excessive amounts of energy to ensure occupant well-being, productivity and to increase the general acceptance of sustainable buildings.

REFERENCES

Australian Bureau of Statistics, 2010. *6302.0 - Average Weekly Earnings, Australia, Nov 2010*.

Building Code of Australia 2008

Fisk, W. J., 2002, *How IEQ affects health, productivity*. ASHRAE Journal May 2002, pp. 56 – 58

Hedge, A., 2000, *Where are we in understanding the effects of where we are?*. Ergonomics, 43(7), 1019-1029

Heschong, L., Okura, S., Wright, R., 2002, *Daylighting impacts on human performance in school*. Journal of the Illuminating Engineering Society, pp. 101-104

Kats, G., 2003, *The costs and financial benefits of green buildings, A Report to California's Sustainable Building Task Force*.

Leather, P., Pyrgas, M., Beale, D., Lawrance, C., 1998, *Windows in the workplace: Sunlight, view and occupational stress*. Environment and Behaviour, 30(6), 739-762

Mallory-Hill, S., van der Voost, T., Van Dortmost, A., 2004, *Evaluation of innovative workplace design in the Netherlands*. In W.F.E. Preiser & J. Visher (eds), Assessing building performance (pp.16-169), London: Elsevier Science Publishers

NABERS, 2009, *Energy Guide for Building Energy Estimates, Version 2009-August*.

Nabil A, & Mardaljevic J., 2005a, *Useful Daylight Illuminance: A New Paradigm to Access Daylight in Buildings*. Lighting Research & Technology, 37(1), 41-59

Nabil A, & Mardaljevic J., 2005b, *Useful Daylight Illuminances: A Replacement for Daylight Factors*. Energy and Buildings, 38(7)

Origin Energy, http://www.originenergy.com.au/price, accessed 15/05/2011

PowerWater, http://www.powerwater.com.au/business/pricing, accessed 15/05/2011.

Property Council of Australia, 2007, *EMET Benchmarks for Office Buildings*

Rawlinsons, 2010, *Australian Construction Handbook 2010*, Rawlinsons Publishing

Reinhart C F, & Walkenhorst O., 2001, *Dynamic RADIANCE-based Daylight Simulations for a full-scale Test Office with outer Venetian Blinds*. Energy & Buildings, 33(7), 683-697.

Reinhart C F, & Andersen M., 2006, *Development and validation of a Radiance model for a translucent panel*. Energy and Buildings, 38(7).

Reinhart, C., 2002, *Effects of interior design on the daylight availability in open plan offices*. Conference Proceedings of the ACEEE Summer Study on Energy Efficient Buildings, Pacific Grove, CA., U.S.A., pp. 1-12

Tregeagle, S., 2011, *Worker time and cost of stability*. Department of Econometrics and Business Statistics, Monash University

Wienhold, J, 2008, *Evaluation methods and development of a new glare prediction model for daylight environments with the use of CCD cameras*. Energy and Buildings, 38(7):743-757