EMERGING TECHNOLOGIES IN BUILDING ENVELOPES

Dr Mark B Luther

SUMMARY OF

ACTIONS TOWARDS SUSTAINABLE OUTCOMES

Environmental Issues/Principal Impacts

- There is a growing expectation for building envelopes to act as flexible and responsive boundary systems between interior and exterior environments.
- In an effort to meet the demands for comfort and environmental responsibility, building envelopes are utilising components of high-technological solutions, resulting in better visibility, greater light transmission, increased energy generation and storage capacity, and improved shading and ventilation.
- New technologies can be integrated with, and even replace, existing building components increasing overall environmental performance.
- Building control strategies have a tremendous responsibility for maximising building performance after all the aspects of technology and passive systems are in place.
- Innovative systems alone are not the answer to high-performance buildings. Refined control strategies are of prime importance to the design of any high-performance system.

Basic Strategies

In many design situations, boundaries and constraints limit the application of cutting EDGe actions. In these circumstances, designers should at least consider the following:

- fuel cell technology, phase-change materials and metal hydrides provide a substitute source of operational energy, potentially release no pollutants, are nearly soundless in operation and have competitive total efficiency values compared to other energy generating systems
- when evaluating the use of photovoltaic energy, consider the building component it could replace (i.e. shading, cladding) and added efficiencies during unoccupied (user absent) periods when solar energy is continuously being collected and put back into the grid
- use of highly reflective surfaces to direct light, such as Solatubes and reflective luminaire baffles
- use of daylight directing devices to allow the switching off or dimming of artificial light
- use of coated glass products that reduce energy transfer through windows
- use of evacuated glass units to insulate building envelopes.

Record the design process of using innovative facade technology.

Producing case studies on these solutions may assist further uptake of the technology within Australia.

Cutting EDGe Strategies

- Consider using controllable glazing systems that provide 100% vision, while reducing glare.
- Consider the total 'value adding' and benefits of integrating new and innovative technologies - it may encourage their uptake within Australia.
- Consider double envelope integration strategies within a building system.
- Approach new technologies with a view to integrating them into a 'whole of building' design approach.

Synergies and References

- *BDP Environment Design Guide*: DES 6, DES 28, DES 36, TEC 4, PRO 19
- Built Environment Research Group, Deakin University, http://www.ab.deakin.edu.au/berg/
- Edmonds, I, Greenup, P, and Mabb, J, 1998, 'Performance of Advanced Daylighting Systems', in *Proceedings of Solar '98*, 36th Annual Conference Australian and New Zealand Energy Society, 25-27th November, University of Canterbury, Christchurch, New Zealand
- Green, MA, 1999, 'Photovoltaics – Recent Developments', *Australian New Zealand Solar Energy Society (ANZSES) Proceedings*, SOLAR '99, Deakin University, Geelong
- Luther, MB, and Reuss, S, 1999, 'A Comparison between Glass and Mass Facades', *Proceedings of the PLEA 1999 Conference*, Passive Low Energy for Architecture (PLEA) Conference, Brisbane, 22 - 24th September

ENVIRONMENT DESIGN GUIDE

EMERGING TECHNOLOGIES IN BUILDING ENVELOPES

Dr Mark B Luther

Advancements in engineering and space technology are increasingly finding application in buildings. Building envelopes are utilising components of high-technological solutions resulting in better visibility, greater light transmission, increased energy generation and storage capacity, improved shading and ventilation and integration with the external environment. This report summarises several technological advancements and suggests forthcoming directions for building envelope design. Many of the technologies presented here have been invented and developed in Australia, yet are not commonly used by the building construction industry.

1.0 INTRODUCTION

In the last 20-30 years the building envelope has undergone some major advancements, developing from an expression of architectural intent into an element of high-tech engineering and design. Reasons for these advancements are increasing expectations of room comfort, greater demand for energy efficiency, and an increased awareness of environmental issues through the 'green' movement (Heusler, 1996). In response to these demands, building envelopes can no longer remain as static expressions of glass and steel, but must be developed into flexible and responsive boundary systems between interior and exterior environments.

The move to mandatory energy targets by governments is requiring the building industry to evaluate the proposed and existing built environment, both quantitatively and qualitatively. In response to this, the building envelope is evolving into an energy intermediary that is sensitive to our natural resources, requiring passive and active control mechanisms. There is a growing expectation for building envelopes to act as a dynamic filter (Daniels, 1995).

1.1 Nature and cell biology – an analogy with building envelopes

Advanced building envelopes may be regarded as analogous to that of the cell membrane. This analogy reflects that nature, at a microscopic level, is dynamic and responsive to its environment.

There are several processes that protect the cell contents and balance the interior cell environment. Through both active and passive diffusion, including osmosis, the constant and favourable integrity of the cytoplasm is maintained to provide the organic and inorganic needs (input requirements) and the removal of wastes (outputs), all of which occur across the cell membrane. The complex composition of the cell membrane is a dynamic shield against the numerous undesirable components of its surroundings. Yet, the membrane recognises, selects and actively absorbs desirable nutrients from this immediate external environment.

Passive diffusion across a membrane is influenced by the concentration of gradients, particle size and shape and electrostatic attraction/repulsion between the particle and the membrane composition. Building envelopes could mimic the role of a cell membrane; rather than being a static component, envelopes can take a dynamic role in responding to various surrounding conditions (Figure 1).

1.2 Polyvalent wall – a wall for all seasons (designed by Mike Davies)

An initial example of a cell-like responsive wall is the 'polyvalent wall' designed by architect Mike Davies (Figure 2). In his 1981 article, 'A Wall for all Seasons' he proposed a multi-performance glazing system which dynamically regulates energy flow between the internal and external environments. The system would provide self-regulating control mechanisms and generate its own electrical power to drive them. This visionary idea has never been realised to the present day, yet, portions of it can be compared to glass substrate technologies such as electrochromics, holographic films and the recent developments with titania (TiO_2) solar cells.

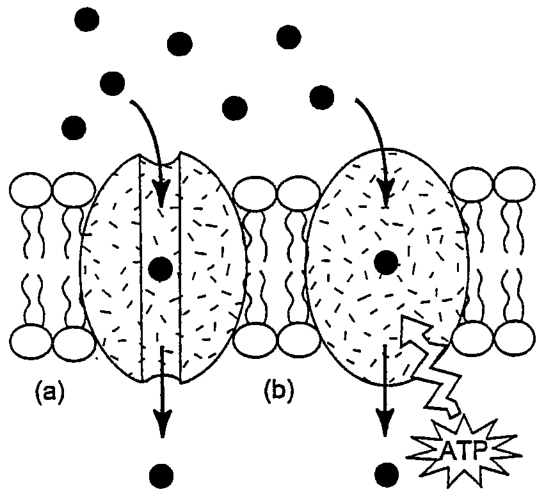

Figure 1. Processes of diffusion through a cell membrane

As with most technological renewable solutions for buildings, cost-effectiveness appears to be a major struggle. Only recently, and not until the design and manufacturing industry began to integrate the technology of photovoltaic solar panels into the building envelope in the form of shading devices, spandrel panels, roof systems and more recently, glazing systems, did the marketplace seriously consider their application and they started to become 'economically' viable. While maximum efficiency is desirable for a photovoltaic panel, it is also necessary to consider how the component is incorporated into the required building element.

Photovoltaic power is becoming more affordable through cost-effective, increased efficiencies and government rebate programs. Efficiencies of an installation often do not consider the many unoccupied (user absent) periods when solar energy is continuously being collected and put back into the grid.

Over the past 25 years the PV industry has become a US$1billion/year industry (Green, 1999). Companies such as Pacific Solar, BP Solar, and Sustainable Technologies International (STI) have established retail outlets and manufacturing operations in Australia. Australia remains one of the leading researchers of this technology and holds the record for the most installed PV area per capita.

At present, the new Titania (TiO_2) Dye Sensitised Cells (DSC) promise a successful future in creating a semi-transparent photovoltaic cell on a glass substrate. The Titantia DSC technology is different from the popular silicone laser grooved cell produced by Pacific Solar, Australia. Titania DSCs, manufactured by STI, Australia applies glass as a substrate. The initial production of TiO_2 cells will be limited when they are commercially introduced in 2002, however high expectations of cell efficiency and economics may lead to the development of a market.

Another example of integrated solar cell advancements is the metal profile PV collectors produced through EnviroPower, Australia. These panels are a thin film triple junction amorphous silicon panel. The laminate is bonded onto BHP cliplock steel profile products. Each panel has an output of 64 watts. A standard home would consist of 22 of these panels. The cliplock panel can be mounted by a general roofer and the electrical work completed by an electrician. Former manufacturers such as Canon Solar have produced similar products consisting of flexible photovoltaic cells. This new product is available through EnviroPower to architects/builders/developers for multi dwelling projects and commercial projects.

2.3 Metal hydrides (MH)

At the time of publication an interesting collaborative project (involving the University of Melbourne, Peter Smithson Assoc, Minesco Pty and Deakin University) involves the development of an integrated solar heat driven metal hydride cooling system in a facade panel. Metal hydrides can have up to 40 times the volumetric energy density of other energy storage systems, thus allowing them to be extremely compact. The metal hydride heat pump (MHHP) system incorporates a solar air collector, as the energy supply, in the typically overheated shadow box (opaque spandrel panel) of a facade system (Figure 4).

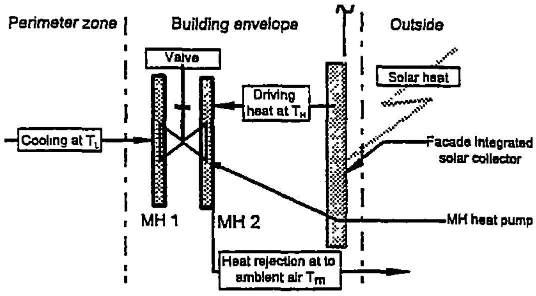

Figure 4. Schematic layout of the metal hydride cooling system (courtesy Peter Smithson Assoc)

The MHHP is a heat driven absorption cooling system, which utilises the heat flows associated with the reversible phase change reaction, possible between hydrogen and MH alloys. Whether a metal hydride absorbs hydrogen (heat release) or releases hydrogen (heat absorption) depends on:

- the temperature of the metal hydride
- the pressure of the hydrogen gas surrounding the metal hydride; and
- the concentration of hydrogen already bound within the MH alloy.

The advantage of this system is in its immediate delivery during periods of increased cooling demand. A metal hydride system will not require the storage of energy for later heating or cooling use, although it can operate this way, if there is a significant delay between peak external and peak internal loading. An integrated metal hydride facade system would lead to a reduction in plant size and peak cooling loads. It would assist in peak-shaving on an air-conditioning plant, providing cooling when demands are highest.

A modular design of the metal hydride heat pump has several advantages:

- They are heat driven and can utilise waste energy sources.
- They have few moving parts and are silent.
- They are compact and can be adapted into the building design.
- When used below their design capacity there is no reduction in performance.
- They are capable of storing heat over time without losses.
- They are environmentally friendly, eliminating ozone-depleting refrigerants.

At this point in time, the project remains in the laboratory. Japanese manufacturers are also researching this technology and have tested a few installations which are different to the integrated facade approaches presented here.

product with an electrically controlled darkening of the glazing material.

Interest in electrochromic glass has been increasing over the past ten years. Electrochromic glass can be actively controlled either manually or by a Building Management System (BMS). By applying a small electric potential to the glass, compounds within the glass undergo an ionisation process (accepting or shedding ions), which influences the transmission characteristics of the glass. The compounds consist of an ion storage layer, an ion conductor and an electrochromic material, sandwiched between two panes of glass or plastic. Figure 5 shows the arrangement and the location of the chemical reaction of the charged ionisation, and where the electrochemical reaction takes place (Compagno,1996). An advantage of this system over thermochromic and photochromic glass is that the change in ionisation is reversible at any time. The idea is that electrochromic glasses can be connected to photosensors, guaranteeing uniform daylight levels.

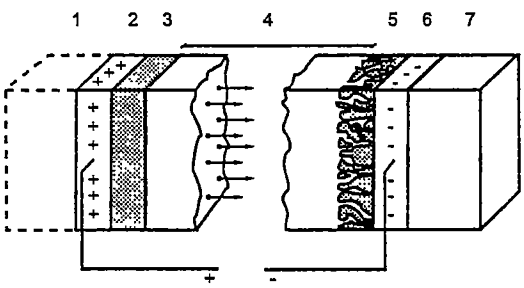

Figure 5. Electrochromic glazing showing ionisation structure (Compagno, 1996)

3.3.3 Holographics

A shading device system incorporated directly into the glass window is achieved through the application of the holograph process. These products are manufactured in Europe, however could easily become available, and possibly manufactured, in Australia if there was a market.

Holographic optical elements (HOE) are used as concentrators for photovoltaic energy or as integrated holographic stacks comprising several holograms. They operate in different ranges of the solar spectrum (wavelengths) for daylighting and shading in glazing systems. The HOE's, either reflective or transmissive, are encoded in dichromated gelatine layers deposited onto a glass (or plastic) substrate. Similar to the vapour deposition coating processes, a response to various wavelengths can be engineered. An asymmetric reflective hologram has been developed for window shading, the properties of which permit an unobstructed view through the window, yet block (reflect) the direct solar radiation at some particular angle of incidence (Figures 6a, b, c, d).

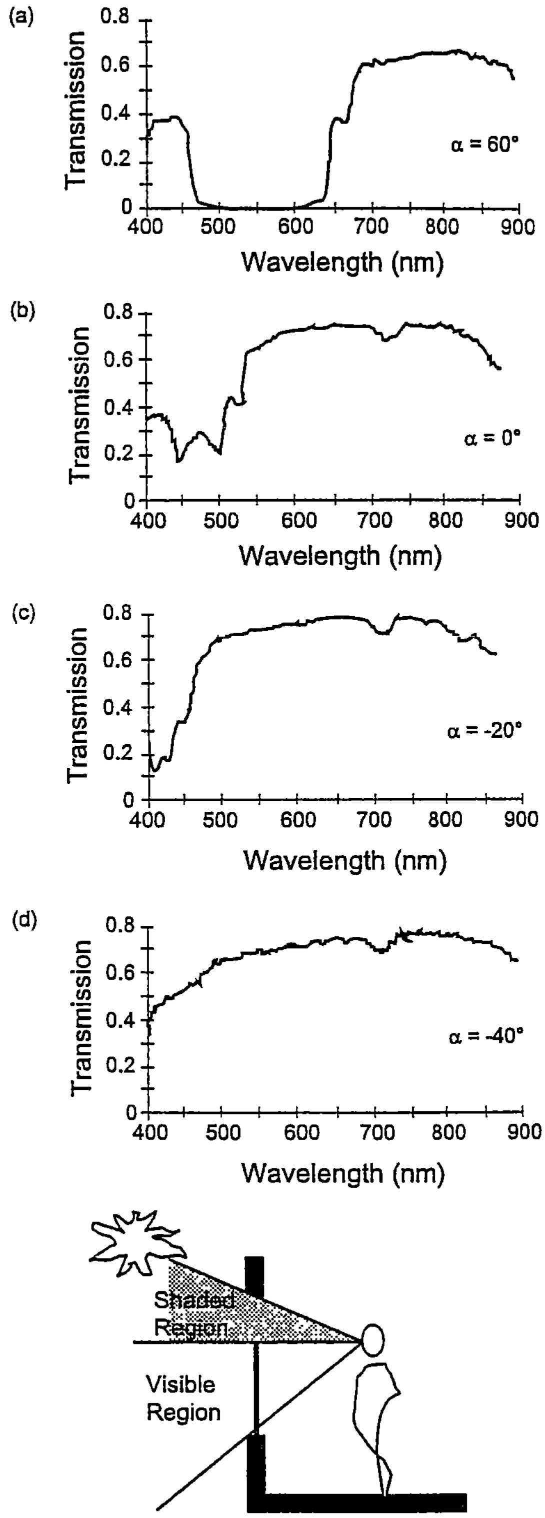

Figure 6. Charting angular selective responses to a solar-shading holographic film (Stojanoff, Schulat and Eich, 1999) with section drawing illustrating the effect on a user

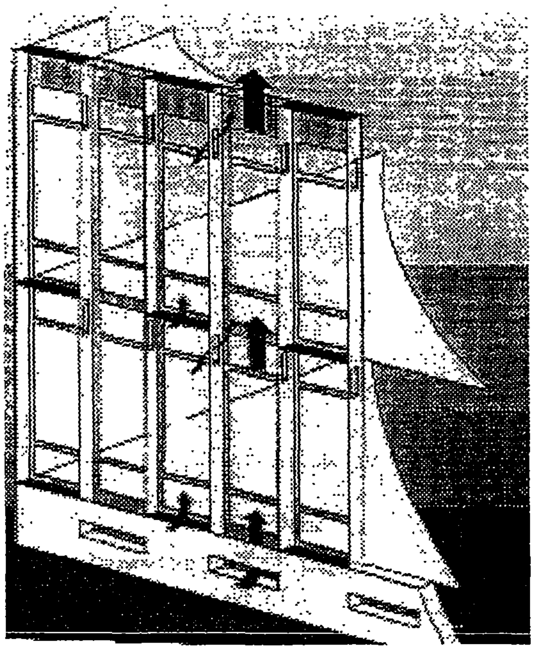

Figure 8. The TWINFACADE double envelope concept (Raatschen, 1994)

An example of desired pressure differentials within the cavity of a double envelope facade is provided in the design of the RWE AG Bank Headquarters in Essen, Germany (Figure 9). In this case the facade is ventilated through siphonage principles similar to an "S" pipe in the plumbing of a water closet. Several adjustable fins make the aperture flexible in opening size. This design facilitates the requirements of different ventilation rates under changing external wind, and internal cavity temperature, conditions.

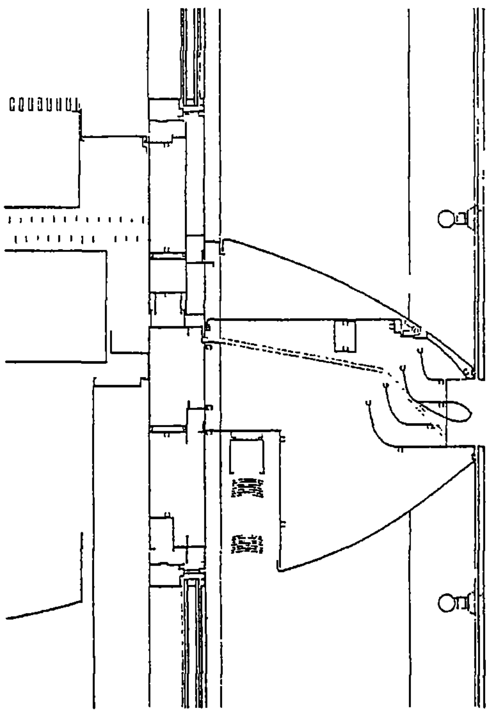

Figure 9. Section of ventilation fins in the double envelope of the RWE Bank (Wigginton, 1995).

The double envelope systems discussed above are the beginnings of promising solutions to dynamic and responsive facade systems. These systems require a program of environmental parameters to be met and incorporated in design. Performance of the double envelope system should be measured against how effective and efficiently they meet the environmental criteria.

An uncomplicated solution utilising a double envelope with off-the-shelf components was designed for the addition of a university library in Melbourne, Australia (Figure 10). Some of the criteria to be met included:

- security while windows are open
- night-time ventilation with open windows
- maintaining diffuse useable daylight while reducing solar loads
- using adjustable venetian blinds in the cavity
- prevention of books being thrown out of the window
- an inexpensive solution to the construction of a double envelope system
- thermal loading of the system to equal that of an opaque wall.

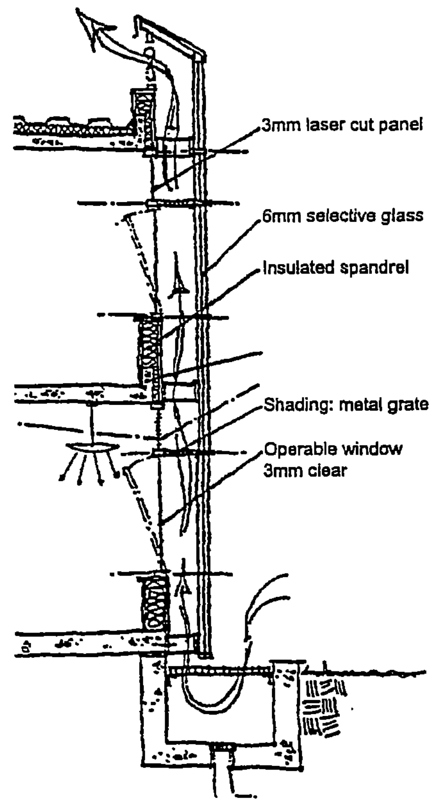

Figure 10. Schematic concept for a double envelope wall on a university library (Luther and Reuss,1999).

Preliminary thermal modelling of the system indicated that there could be a 50% reduction in plant size, as well as an annual energy consumption reduction of 70% when compared to the application of a conventional single glazed facade (Luther and Reuss, 1999).

performance system. In an effort to further advance successful building systems and their control, the Built Environment Research Group at Deakin University is developing a facility together with several university, industry and government partners. It is intended that such a facility will provide more information on the integration of systems similar to those presented in this paper.

REFERENCES

Brey, S, 1997, *Simulation of the Heat and Mass Transfer in Coupled Metal Hydrides for Heat Pump Applications*, The University of Melbourne, Master Thesis Department of Mechanical Engineering, Melbourne

Burt, T and Li, H, 1996, 'Sick Building Syndrome: Thermal Aspects', in *Australian Institute of Building Papers*, Vol 7

Collins, RE, Turner, GM, Fischer-Cripps, AC, Tang, JZ, Simko,TM, Dey, CJ, Clugston, DA, Zhang, QC, and Garrison, JD, 1995, 'Vacuum Glazing – A New Component for Insulating Windows', in *Building and Environment*, Vol 30, No. 4, pp 459 - 492

Compagno, A, 1996, *Intelligent Glass Facades: Materials Practice Design*, Birkhauser Publishers, Basel

Daniels, K, 1995, *The Technology of Ecological Building, Basic Principles and Measures and Ideas*, Birkhauser Verlag, Basel

Davies, M, 1981, 'A Wall for all Seasons,' in *RIBA Journal*, February, pp 55 - 51

Edmonds, I, Greenup, P, and Mabb, J, 1998, 'Performance of Advanced Daylighting Systems', in *Proceedings of Solar '98*, 36th Annual Conference Australian and New Zealand Energy Society 25-27th November, University of Canterbury, Christchurch, New Zealand

Green, MA, 1999, 'Photovoltaics – Recent Developments', *Australian New Zealand Solar Energy Society (ANZSES) Proceedings*, SOLAR '99, Deakin University, Geelong

Heusler, W, 1996, *High-Grade Facades for Office Buildings: The Double-Skin Concept*, Joseph Gartner Co GmbH Postfach 20/40, Gundelfingen D-89421, Germany.

Johnson, JE, 1991, *Low-E Glazing Design Guide*, Butterworth-Heinemann Publishers, Woburn

Kiechle, H, 2001, 'Aegis Hyposurface', *Architectural Review Australia*, 075 May, Niche Media Pty Ltd, Melbourne

Luther MB, and Reuss, S, 1999, 'A Comparison between Glass and Mass Facades', *Proceedings of the PLEA 1999 Conference*, Passive Low Energy for Architecture (PLEA) Conference, Brisbane, 22-24th September

Perlin, J, 1999, *From Space to Earth: the story of solar electricity*, aatec Publications, Ann Arbor, Michigan

Raatschen, W, 1994, 'Energy and Ventilation Performance of Double Facade Office Buildings', *Innovative Fassadentechnologie: Proceedings Workshop Lichtlenkende Bauteile*, Institut fur Licht u Bautechnik Fachhochschule Koln, 2–4th November

Saman, W and Vakilaltojjar, S, 1997, 'Evaluation of a Thermal Storage System Employing Multiple Phase-Change Materials', *Proceedings of Solar '97*, 35th Annual conference Australian and New Zealand Energy Society, Canberra, 1–3rd December

Shaw, M and Pearsall, N, 1997, 'The Architecturally Integrated Photovoltaic Facade at Northumberland Building University of Northumbria Newcastle-Upon-Tyne', *ICBEST '97 Proceedings International Conference on Building Envelope Systems and Technology*, University of Bath, Bath, April, pp 363–368

Smith, GB, McPhedran RC, and Derrick, GH, 1985, 'Surface Structure and the Optical Properties of Black Chrome', *Applied Physics*, Springer Verlag Publishers

Stojanoff, CG, Schuette, H, Schulat, J, and Eich, M, 1999, 'Bandwidth and angle selective holographic films for solar energy applications', *Proceedings of SPIE Vol 3879*, Solar Optical Materials XVI, pp 38–49

Swift, PD, Smith, GB, and Franklin, J, 1999, 'Light-to-light efficiencies in luminescent solar concentrators', *Proceedings of SPIE Vol 3879*, Solar Optical Materials XVI, pp 21–28

Wiggington, M, 1995, *Glass in Architecture*, Phaidon Press Ltd, London

ADDITIONAL SOURCES

BP Solar: http://www.bp.com.au/

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City of New York, 1999, *High Performance Building Guidelines*, Department of Design and Construction, April

Enviropower, PO Box 27, Richlands, Queensland 4077 Ph: 1300 364 786 Fax: 1300 364 329 www.cyb.com.au/industrial/enviropower

Pacific Solar: http://www.pacificsolar.com.au/

Pierlight Lighting, KW/2 Reflective Coating, Pierlite Pty Ltd 96–112 Gow Street, Padstow, NSW, 2211, Australia

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Sky Solutions, a division of Skydome, Sydney, www.skydome.com.au

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