ENVIRONMENT DESIGN GUIDE

DESIGN FOR ECO-SERVICES

PART A – ENVIRONMENTAL SERVICES
PART B – BUILDING SERVICES

Janis Birkeland

Summary of

Actions Towards Sustainable Outcomes

Environmental Issues/Principal Impacts

- The world already exceeds its ecological carrying capacity due to the use of the conventional systems of development in place today (e.g. fossil fuel driven, centralised industry).
- Even if the human population does not continue to grow, our systems of development would not be sustainable, because the environmental and economic costs of conventional development outweigh the benefits over time.
- Green buildings are not sustainable as they replace nature. Design aimed to mitigate the negative impacts of existing unsustainable systems is not good enough. We need to go beyond even regenerative design to eco-positive design.
- Positive Development is theoretically possible, by increasing the ecological base and public estate, if we learn to design for integrated eco-services.

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:

- Look for eco-retrofitting opportunities before considering new construction.
- Use natural systems to clean the air, water and any unavoidable waste or pollution produced by the development to ensure what comes out of a building is healthier than what went in (e.g. humans, water, air).
- Avoid contributing to the heat island affect and mitigate the existing urban microclimate caused by surrounding properties.
- Ensure zero operating energy and greenhouse gas emissions over the life cycle of the project.
- Minimise embodied energy and waste in construction by, for example, using organic materials where possible.
- Use passive solar systems for heating, cooling and ventilating.
- Avoid sites likely to be prone to floods, earthquakes, severe storms, droughts, bushfires, and so on.

Cutting EDGe Strategies

- Find ways to increase natural capital beyond original (pre-settlement) site conditions (e.g. using living roofs, walls, balconies, facades and/or atria) for multi-functional benefits.
- Consider integrating aquaculture, permaculture, living machine, algae-tecture, hydroponic systems and so on.
- Ensure on site and nearby indigenous ecosystems are healthier, more bio-productive, greater in size, and more resilient after development than before.
- Integrate eco-services with existing urban infrastructure and building structures for spatial and structural efficiency.
- Integrate human and natural functions or eco-services to optimise space for positive environmental gains.
- Design to improve relationships between individuals, society and nature by, for example, providing green public space and amenities, and access to the means of survival (e.g. food security in urban areas).
- Design the structures to be adaptable, deconstructable and even reversible (e.g. compostable).

Synergies and References

- *Environmental Design Guide:*
  - GEN 4: Positive Development: Design for Eco-Services
  - GEN 6: Ecological Waste: Rethinking the Nature of Waste
- Birkeland, J, 2008, Positive Development: from Vicious Circles to Virtuous Cycles through Built Environment Design, Earthscan, London, UK.

ENVIRONMENT DESIGN GUIDE

DESIGN FOR ECO-SERVICES
PART B – BUILDING SERVICES

Janis Birkeland

Without the virtually free services of nature like clean air and water, humans would not last long. Natural systems can be incorporated in existing urban structures or spaces to add public amenity, mitigate the heat island effect, reduce pollution, add oxygen, and ensure water, electricity and food security in urban areas. There are many eco-solutions that could radically reduce resource consumption and pollution and even provide surplus ecosystem services in the built environment at little or no operational cost, if adequately supported by design. This is the second part of a two part paper that explains what eco-services are, then provides examples of how design can generate natural as well as social capital. Using examples of actual and notional solutions, both papers set out to challenge designers to 'think again', and invent ways of creating net positive environmental gains through built environment design.

Keywords:
Positive Development, design for eco-services, ecological architecture, eco-positive design, regenerative design, natural security, ecosystem goods and services, green infrastructure

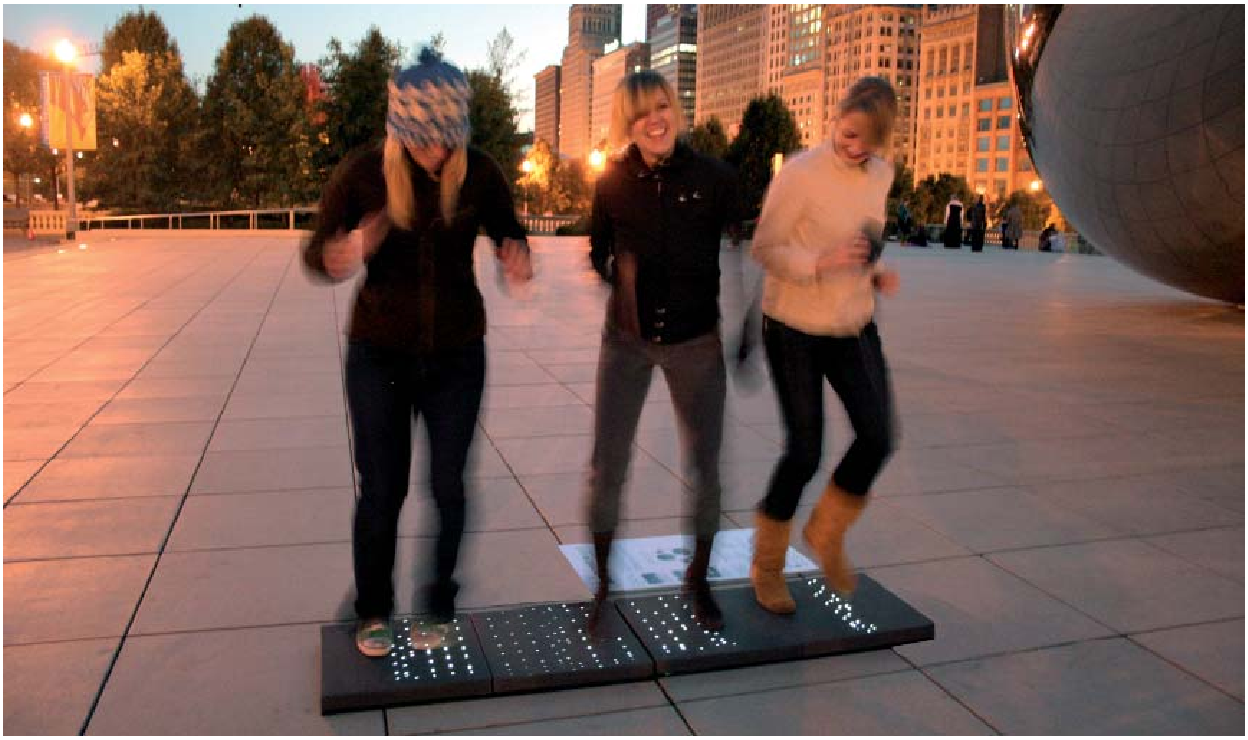

Figure 1: Energy harvesting flooring that converts kinetic energy into electricity
(Source: Courtesy of POWERleap, Photo: 2007)

1.0 INTRODUCTION

In the first part of this two part paper, the idea of design for eco-services was explained. Eco-services are the 'free' services of nature such as pollination, air cleaning, pollution treatment, carbon sequestration and water purification. Examples were provided of such environmental services that could be gained at low cost by integrating natural systems with the built environment.

What are today called 'green buildings' are not sustainable. In their production and construction, even 'zero carbon' buildings destroy habitats and ecosystems, and contribute to the cataclysmic rate of species reduction. The loss of any single species (like pollinators) could conceivably cause the food chain to collapse. We have already exceeded the Earth's carrying capacity (UNEP, 2005). Therefore, if we are to address issues like greenhouse gas emissions, resource security, the oxygen deficit of cities, and so on, we will need to design *for* nature – not just 'with' or 'like' nature. Nature took four billion years of 'intelligent design' to evolve, so we cannot improve nature, but we can expand the ecological base in urban areas. It is theoretically possible to increase the ecological base over pre-settlement conditions, because of the many levels and edges created by buildings and infrastructure in existing built environments.

In part one, regenerative and eco-positive design were distinguished. 'Net positive' means the ecological base is greater in size and more resilient after construction than before, even accounting for the materials and energy used in construction. Few designers even think to design buildings that are ecologically net positive, because our theories, assessment tools, and construction materials and methods still reflect industrial age thinking. For example, life cycle assessment to date only measures negative impacts. Positive Development is not just about eco-positive design, it is a re-think of the decision frameworks, design methods and assessment tools that create subtle but powerful biases against sustainability. A comprehensive paradigm shift which encompasses new modes of environmental ethics, management, planning, and design is needed to deliver net Positive Development (Birkeland, 2008).

Not only do eco-services make life possible, with good design they could provide more physical and psychological comforts and health than conventional architecture. There are already many eco-solutions that can improve life quality and provide essential services,

Figure 2: Hemp based products used for wall construction

(Source: Lime Technology Limited, Copyright © 2000-2010)

while radically reducing resource consumption, and making the urban environment a healthier and more secure place to be. However, they have not been integrated with building structures, so they are still perceived as 'extras'. The author's students at the Queensland Institute of Technology (QUT) have discovered many opportunities to integrate ecosystem services with existing urban functions, such as bridges, alleys, buildings and landscapes, to add ecological value at low cost.

This part provides examples of building services that can be supplemented by natural systems to, for example, reduce energy and greenhouse gas emissions.

2.0 MATERIALS USE AND REUSE

2.1 Materials

Conventional building materials contain solvents, volatile organic compounds, formaldehyde, asbestos, and so on, that are linked to serious health risks (Terry, 2002). Such harmful building materials are usually produced through centralised, industrial, fossil fuel-driven processes, perceived to be 'efficient'. Centralised manufacturing is vulnerable to economic crises; centralised electricity generation is subject to black outs; centralised water can be contaminated and depleted; centralised heating and cooling plants can fail, and so on. These manufacturing processes are rarely efficient from a whole systems or 'eco-logical' view. Moreover, geographically limited non-renewable power supplies like oil and uranium usually entail the dominance of global markets by a limited number of powerful trans-national corporations. As we have seen in the Middle East in recent years, the coveting of these resources can lead to political instability (as explained in detail by Scheer, 2002). Many fossil fuels can be replaced by algae farms using only salt water and carbon dioxide emissions.

Compostable, non-toxic, bio-based construction materials often have lower life cycle costs and can be much healthier in production, use and disposal (Berge, 2002). Examples include strawboard and wheatboard, as well as strawbale and earth construction, as these do not require toxic binders. When buildings of organic components are renovated, discarded materials could be composted in urban parks or on site to contribute to urban soil fertility, rather than being sent to landfill where they become a liability. Producing such organic building materials on farms in regions close to their end-use destination can also help to create light industry in rural areas, diversify agricultural production and revitalise rural communities (Birkeland and Schooneveldt, 2003). Of course, biodegradable materials are only sustainable if they come from sustainable farming methods. Their relative life cycle impacts depend on what, how and where the agricultural materials are farmed, and the total resource flows and fuels involved in their production. Some examples follow and others are provided in the EDG

Figure 3: Shipping containers reused as accommodation

This residential project saw 30 containers built into 22 units at the Container City II at Trinity Buoy Wharf, London Docklands.

(Photo: Courtesy of www.containercity.com, 2002)

paper PRO 11: *Renewable Resources – A Survey of Materials* (Gelder, 2002).

Hemp: Plants can replace virtually all plastic products, as carbohydrates can be used instead of petrochemicals (Danenburg, 2002). Hemp is a hardy plant that requires less water and fertiliser than similar crops It has both high thermal mass and insulative properties - a rare asset in building materials. In other words, it can be poured like concrete as 'hemcrete', or be used as insulation loose or in batts (www.limetechnology.co.uk). Whole houses have been made from hemp in France and also in the USA for demonstration purposes.

Bamboo: Bamboo is the fastest growing strong, woody plant in the world. It can be used to manufacture building materials such as plywood, laminated floorboards and beams, particle board, bio-char and other uses. Some species may grow over a meter a day, making bamboo more suitable than trees for sequestering carbon quickly. Up to 15-20 per cent of the worlds bamboo can be harvested annually without diminishing the stock (Cusack, 2002).

2.2 Recycling

There is no waste in nature as everything is recycled in an infinitely complex system – automatically. Waste generation in our society has continued to increase, due to the disposability, excessive packaging, 'single-function' design and disposable use, planned obsolescence, and constantly updated technology (Birkeland, 2007b). Construction is particularly wasteful under current norms. For example, buildings use over 3 billion tons per annum or over 40 percent of materials worldwide, and contribute 44 percent of landfill waste (Roodman and Lenssen, 1995).

Waste can be greatly reduced by good design. Books like *Cradle to Cradle* (McDonough and Braungart, 2002), *Natural Capitalism* (Hawken, Lovins and Lovins, 1999), and *Factor 4* (Weisacker, Lovins and Lovins, 1997) give many examples of how profits have been increased by saving resources through closed loop systems, where waste is reused in other processes. Updated information is provided in Factor 5 (Weizsacker, et al 2010). Where we lack the ability to design waste out of a system, we can turn waste into new products, jobs and resources. Recycling usually means 'down-cycling' to lower-value products, and the recycling process entails energy use and other impacts (Hill, 2002). However, good design would also prioritise healthy and necessary products with multiple functions, and would 'up-cycle' materials. Examples of turning waste to higher value products or up-cycling follow.

Furniture from waste: 'Fun' outdoor furniture has been made from used CDs, skis, baseball bats, and skateboards (Poole, 2006), high quality timber furniture has been produced from old shipping pallets (McDonough and Braungart, 2002), and Dutch designer Tejo Remy has designed seats that 'up-cycle waste' by constructing them from a steel frame and dozens of tennis balls. Not deemed suitable for sale, these balls would have otherwise become landfill (Inhabitat, 2009). Of course, recycling only slows their progress to landfill and does not prevent it.

Shipping containers: Heavy steel shipping containers were created to suit an industrial age when efficiency was interpreted merely in economies of scale, not resource reduction. They embody a lot of energy and often travel one way only, to be left empty and rusting at their destination. There are dozens of examples around the world where used shipping containers have been modified, connected and stacked to create office and housing structures for a fraction of the cost, labour, and resources of more conventional materials (Figure 3). Successful examples range from portable cabins to large hotel and office structures.

3.0 BUILDING SERVICES

3.1 Lighting and views

Natural lighting, especially in combination with good ventilation and views, etc, reduces sick leave, absenteeism and workers' compensation claims, and

Figure 4: Light transmitting concrete
(Photo: Aron Losonczi, www.litracon.huLitracon)

increases employee productivity measurably. (EBN, 1999). This is important, as salaries are 85 percent of the costs of most businesses. Retrofits for daylighting can pay for themselves in a short period of time, in some cases in less than a year, as documented by Joseph Romm in *Cool Business* (Romm, 1999).

Recent research has re-confirmed a relationship between work environments and productivity (Bell et al, 2008). Viewing gardens in hospitals reduce stress, medication, recovery time and surgical complications (Cooper-Marcus and Barnes, 1999). Daylighting has also been shown to improve performance in schools (EBN, 1999). Designing our buildings to be more like gardens than machines for living would be an inexpensive and rewarding form of preventative medicine. We are gradually giving more credence to qualitative research and open natural systems, and have more indicators (such as stress levels in people living with and without urban greenery).

Given the benefits of natural lighting, along with significant energy savings, the challenge is to access daylighting within the limitations of internal rooms, poor solar access and need for fire rated walls.

Light-transmitting concrete: One manufacturer has produced a product with optical fibres running through prefabricated concrete blocks or panels to transmit light from one side to the other (Litracon, 2009). It is claimed that the optical fibres do not significantly affect the structural capabilities of the concrete and can transmit light at least 15 metres. Thus, interesting use of daylighting need not necessarily be limited to narrow or light weight structures (Figure 4).

Mirrors: Mirrors on the inside or outside of buildings have been used to bounce light into dark spaces, sometimes adding interesting visual effects as well. Reflective surfaces on rotating shading devices can serve a variety of useful functions in both winter and summer (Wrigley, 2005).

Hybrid solar lighting: Roof mounted tracking systems have been developed which can move with the sun to maximise the harnessing of sunlight. Some, collecting light into a beam, focus the sunlight onto optical fibres connected to hybrid light fixtures. These have special diffusion rods that spread the light out in all directions. One collector powers about eight hybrid light fixtures which can illuminate approximately 10m2. A range of low-impact lighting options is provided by Garcia-Hansen (2006).

3.2 Heating and cooling

The energy consumed by the built environment is about 40 percent of total energy consumption in Australia. Energy use is growing rapidly in the built environment because of reliance on mechanical means for heating and cooling. Much of this could be reduced by passive solar retrofitting such as

Roof mounted daylight collecting

Interior light by optic fibre transmitted daylight

Figure 5: Solar lighting via optic fibres
(Source: www.Parans.com)

attaching greenhouse conservatories, or Trombe walls to existing buildings. Readers of this journal would know that there are many homes that are 'energy autonomous'; that is, they do not need external sources of energy for heating and cooling (Vale and Vale, 2002, 2005, Mobbs, 1998). Even though Australia has some good examples of passive design, and the principles understood for thousands of years, they are rarely employed in building. The Christie Walk urban village in Adelaide for example exemplifies best practice integrated passive solar and community design (Downton, 2009). The project imbeds strawbale construction and a green roof into inner urban medium density residential construction. And Melbourne City Council's 'Council House 2' office building employs passive solar principles and utilises 'night purging' of the interior with cool night air, and shower towers for providing cool air at the multi-story building scale (see www.melbourne.vic.gov.au/Environment/CH2).

Many books on passive solar design have been available for over thirty years, so the basic forms of passive solar design are not discussed here. However, a couple of slightly less familiar passive design concepts are provided.

Wind towers and shower towers: In hot dry climates, wind towers can scoop air into the building where it is cooled by water through evaporative cooling. This passive cooling system was used in ancient buildings in desert regions. Shower towers are similar, but use falling water in a tube to draw air into the building, as the falling water displaces the air, and the evaporation of the water cools it. The cooled air can then be drawn into the building at floor level or in ducts (Webster-Mannison, 2003, Prelgasukas, 2003). The technology has issues yet to be fully resolved, such as the potential for legionnaires disease to develop with dampness, however heat exchangers could potentially solve this by separating pre-heated or pre-cooled air from that in the room (Zeiler and Boxam, 2008).

Solar stacks: Sometimes called 'solar chimneys', these use the stack effect to draw heat out of the building through a vent in a dark tower that exceeds the height of the roof. This works using the principle that air heated in the dark heat absorbing 'chimney' will draw cooler air through the building interior below as it does so. This can be combined with rock storage for warm or cool air, as in the 'solar core' which is detailed futher in the book by the author et al. (Paten, Birkeland and Pears, 2005). Air cooled by being drawn over a shaded pool of water, or even the air-cooled water itself, can be circulated through the home in the same way as water or air heated by a solar collector, thus cooling the interior.

Reverse Trombe wall: Conventional Trombe walls create an air space between an internal masonry wall and glazed external wall, which is orientated to catch winter sun. The air heated within the cavity between these two surfaces is then circulated into the building interior by convection in order to heat it. In summer, the glass is shaded. Many Australian suburban homes have been built with brick veneer construction, which offers little thermal benefit. However, a Trombe wall can be retrofitted onto existing homes by adding a glazed box over an existing external masonry wall, with vents drilled through the wall at the top and bottom. For lighter weight buildings without masonry walls, Trombe walls could be similarly retrofitted (explained further in the author's book, 2008).

3.3 Electricity production

Developments in wind and solar energy are extremely rapid, and the rise of oil and coal prices will eventually drive more investment in renewable energy research

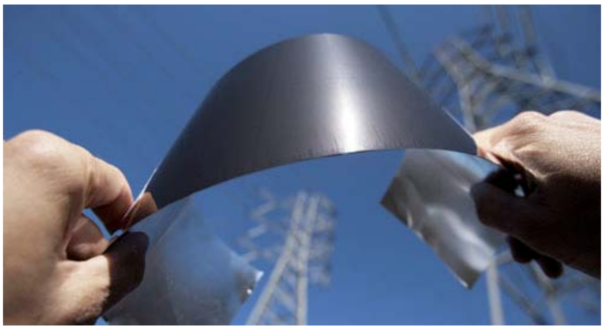

Figure 6: Flexible solar cells printed on metal foil (Source: Courtesy of Nanosolar)

and development. Solar and wind energy are still more expensive than that generated from fossil fuels, as the externality costs of fossil fuels are not directly linked to their purchase price (Myers< N, Kent, J, 2001). Fossil fuels have always received more direct and indirect subsidies over the decades than renewable energy (Diesendorf, 2007).

Renewable energy saves money over time, while most decorative features of buildings have no payback period, and their production entails huge amounts of embodied energy. To create a level playing field, project proponents should be required to compare the payback period of proposed fossil fuel systems and alternative renewable technologies in impact assessments.

Solar hot water is now recognised as a good, safe investment, which pays for itself in electricity or gas savings in just a few years, and use of wind generators and photovoltaic cells are rapidly expanding worldwide. Standard PV arrays can be designed to serve other functions such as a sturdy shading structure to reduce cooling loads. New paper thin PV have been integrated with building skins and signage, and clear versions added to windows, or even interleaved within window glass itself (www.dyesol.com).

Urban wind: The value of urban wind turbines has been questioned due to the irregular nature of wind in urban environments, however, more recently developed vertical shaft wind generators are relatively good with intermittent wind conditions. A roof with a 3 metre vertical rise and a 20 per cent angle will provide nearly a 200 per cent increase in the amount of wind energy that is available (James, 2009). Similar accelerated wind can be created by building design as in the Bahrain World Trade Centre, where three wind turbines are placed between two towers. They are expected to provide 10-15 per cent of the power for both towers, operating 50 per cent of the time.

Solar glass and foil: There are many new products that promise to generate solar electricity using transparent solar cells. Nanotechnology is being used to print PV cells directly onto flexible film or foil sheets. These flexible films, created from monocrystalline silicon material, may be transferred to an existing façade or other surface. Another product, 'PowerSheet' is as thin as a layer of paint and transfers sunlight to power cheaply (Moyer, 2007) (Figure 5).

Crowd farming: Kinetic collectors have been used to collect kinetic energy in the floors of several nightclubs in Europe (Figure 1). The concept of crowd farming will be used in a Tokyo train station to power ticket gates and display systems, and is expected to produce 1,4000 kw per day. A revolving door can also be used to capture energy, as developed by American designers (Fluxxlab, 2009). The energy caused by vibrations on bridges has also been harnessed to supplement the bridge's sensors and lighting. 'Exercycles' can be connected to computers for supplementary power while encouraging healthier workplaces.

4.0 URBAN SERVICES

4.1 Resistance to Natural Disasters

Buildings have been seen as 'shelters' against nature, so they have been designed to exclude nature from urban areas, except as decoration (Hirst, 2002). Ironically, this approach to design has increased the incidents and impacts of natural occurrences like storms, floods and fires (Heal, 2000, Daily and Ellison 2002). For example, the heat island effect increases the frequency and severity of storms around urban areas (Velazquez 2008). While fires, floods and droughts cannot always be avoided, good planning and design can reduce the chance of their occurrence and/or the damage that they cause when they do happen.

After a fire, damaged buildings are generally bulldozed and rebuilt in the same fire-prone environment. Fire prevention design strategies are generally costly and ineffective. Avoiding eaves or complex roofs reduce the chance of embers catching on the home, but offers little protection in a fire, compared to sprinklers on the roof. Expensive capital and resource intensive flood barriers have exacerbated the impacts of larger floods. Then, after floods, buildings are often rebuilt on the same flood plains with marginal flood mitigation measures (Daily and Ellison, 2002).

Fire mitigation: Multi-purpose recreational facilities with emergency sanctuaries (with oxygen supplies, ponds, water sprays, and underground water cisterns) could help to protect people, flora and fauna and slow down fires. Any habitat sacrificed for such areas could be offset by creating more green roofs with sprinklers and nesting places. As long as these facilities provide multiple functions, fire sanctuaries need not cost any more than conventional recreational facilities.

Flood mitigation: Sea levels are projected to rise up to a metre by 2100. For every vertical metre of sea level rise we can expect about 100 horizontal metres of coastal flooding (Globalwarming-awareness, 2007). Some Dutch homes have been built on solid ground but are designed to float like a boat hull (Inhabit, 2007). Homes in flood prone areas can be retrofitted with pontoons, so that they can float in a flood and also store water in a drought (e.g. the 'Amphibious' foundation system). Alternatively, a rubber skirt can be fixed around the building and be lifted up in severe weather called a defence system.

Earthquake and cyclone mitigation: Earthquakes and cyclones kill thousands of people each year at a far greater cost than that of prevention. Mud brick buildings can be reinforced by wire to reduce the risk of death during an earthquake or cyclone. Larger masonry buildings have been retrofitted with bamboo to reduce damage for long enough to allow evacuation. Safety film products are available which meet the same break-safe requirements as tempered safety glass to hold glass shards together in extreme storms. Custom-designed 'nets' for covering homes in cyclones is also a possibility.

5.0 CONCLUSION

As theses two papers illustrate, natural systems could be integrated with the built environment to provide environmental and building services at low cost. These could incrementally but simultaneously replace 'terminal' technologies that use fossil fuels. In synergistic combinations with passive water and solar design, such eco-solutions could conceivably generate net positive ecological impacts over a development's lifespan.

Improving the built environment will entail a paradigm shift from managerial approaches (characterised by 'numerology'), to a positive proactive design-based approach. Any development that leads to net positive ecological impacts, saves resources and makes money while making everyone better off, is a good investment. Positive Development (Birkeland, 2008) provides a process for identifying and prioritizing the most worthwhile eco-positive urban retrofitting projects.

BIOGRAPHY

Dr Janis Birkeland, BA (art), MA (architecture), JD (law), and PhD (sustainability) was a registered architect and attorney in the USA and is now Professor of Architecture at QUT. She worked as an artist, advocacy planner, architect, urban designer, city planner and attorney in San Francisco before moving to Australia in 1981. She has taught architecture for the last 15 years, as well as many courses on sustainable development. She has written over 100 publications on the built environment and sustainability and given over 100 invited lectures.

REFERENCES

Bell, J, et al, 2008, *Productivity and Health in Commercial Office Buildings: Guidelines and benchmarks for facilities management*, Queensland University of Technology, Brisbane.

Berge, B, 2002, *Ecology of Building Materials*, translated from Norwegian by Filip Henley with Howard Liddell, Architectural Press, Oxford, UK.

Biosphere Home Farming, 2009, viewed April: www.yankodesign.com/2009/03/17/the-ultimate-recycle-bin-nourishes-as-well.

Birkeland, J, 2003b, workshop presentation for green design leaders, University of Canberra.

Birkeland, J, 2007a, 'Positive Development: Design for Eco-Services', *Environmental Design Guide*, GEN 4: Australian Institute of Architects, Melbourne.

Birkeland, J, 2008, *Positive Development from Vicious Circles to Virtuous Cycles through Built Environment Design*, Earthscan, London, UK.

Birkeland, J, and J, Schooneveldt 2003a, *Mapping Regional Metabolism: A Decision-Support Tool for Natural Resource Management*, Land and Water Australia, Canberra.

Cooper-Marcus C, Barnes, M, 1999, *Healing Gardens: Therapeutic Benefits and Design Recommendations*, Wiley, New York, USA.

Cusack, V, and Yiping, L, 2002 'Bamboo as a building resource', in J, Birkeland (ed.) *Design for Sustainability: A Sourcebook of Integrated Eco-logical Solutions*, Earthscan, London, UK. pp201–204.

Daily, GC and Ellison, K, 2002, *The New Economy of Nature*, Island Press, Washington, DC., USA.

Danenburg, J, 2002, 'Hemp architecture', in J, Birkeland (ed) Design for Sustainability: *A Sourcebook of Integrated Eco-logical Solutions*, Earthscan, London, UK. pp. 205–208.

Diesendorf, M, 2007, *Greenhouse Solutions with Sustainable Energy*, University of New South Wales Press, Sydney.

Downton P, 2009, Ecopolis: *Architecture and Cities for a Changing Climate*, CSIRO Publishing / Springer, Melbourne.

Duffy, K, 2004, 'NASA studies how to cool area as heat builds up', *Atlanta Journal Constitution*, p.382.

Dyesol, 2009, viewed April: www.dyesol.com

EBN (Environmental Building News), 1999, 'Productivity and green buildings', *Environmental Building News*, vol 8, no 9.

Fluxxlab, 2009, viewed April: www.fluxxlab.com

Garcia-Hansen, V, 2006, *Innovative daylighting systems for deep-plan commercial buildings*, PhD thesis, Queensland University of Technology, Brisbane. http://eprints.qut.edu.au/16709/

Gelder, J, 2002, Renewable Resources – A Survey of Materials, *Environment Design Guide*, PRO 11, Australian Institute of Architects, Melbourne.

Globalwarming-awareness, 2007

Harrison, G, 2009, 'Challenges of Sustainable Waste Management in a Capital City', *Zero Waste Summit '09*, Sydney, December 1.

Hawken, P, Lovins, A and Lovins, H, 1999, *Natural Capitalism: Creating the Next Industrial Revolution*, Earthscan, London, UK.

Heal, G, 2000, *Nature and the Marketplace: Capturing the Value of Ecosystem Services*, Island Press, Washington, DC., USA.

Hempembassy, 2009, viewed April: www.hempembassy.net/hempe/resources/BuildingwithTradicalHemcrete.pdf

Hill, G, 2002, 'Designing waste', in J, Birkeland (ed) *Design for Sustainability: A Sourcebook of Integrated Eco-logical Solutions*, Earthscan, London, UK. pp. 43–45.

Hirst, A, 2002, 'Permaculture and Design Education', in J, Birkeland (ed) *Design for Sustainability: A Sourcebook of Integrated Eco-logical Solutions*, Earthscan, London, pp. 95-58.

IFRC (International Federation of Red Cross and Red Crescent Societies), 2004, *World Disasters Report 2004*, chapter 2 summary, viewed April 2009: www.ifrc.org/publicat/wdr2004/chapter2.asp.

Inhabitat, 2009, .viewed April : www.inhabitat.com

James, Peter, 2009, ARUP engineer, personal communication

Litracon, 2009, viewed April: www.litracon.hu

Limetechnology, 2009, viewed April: www.limetechnology.co.uk

McDonough, W, and M, Braungart, 2002, *Cradle to Cradle: Remaking the Way we Make Things*, McDonough, W, and M, Braungart, 2002, Cradle to Cradle: Remaking the Way we Make Things, North Point PR, Ellesmere Port, UK

Melbourne City Council, 2009, viewed April: www.melbourne.vic.gov.au/Environment/CH2

Mobbs, M, 1998, *Sustainable House*, Choice Books, Sydney.

Moyer, M, 2007, 'The New Dawn of Solar', *Popular Science*, viewed 2007: www.popsci.com.au/popsci/flat/bown/2007/green/item_59.html

Myers, N, and Kent, J, 2001, *Perverse Subsidies: How Tax Dollars Can Undercut the Environment and the Economy*, Island Press, Washington, DC., USA.

Paten C, J Birkeland and A, Pears, 2005, 'Greening the Built Environment' in Hargroves, C, and M, Smith, *The Natural Advantage of Nations*, Earthscan, London, UK.

Paten C, Birkeland, J, and Pears, A, 2005, 'Greening the built Environment' in Hargroves, C, and Smith, MH, 2005, *The Natural Advantage of Nations, Earthscan*, London, UK, pp. 346-70.

Poole, B, (ed) 2006, *Green Design*, Mark Batty Publisher, New York, USA.

Portablefarms, 2009, viewed April 2009: www.portablefarms.com

Prelgasukas E, 2003, 'Enhanced Natural Ventilation in Hot Arid Lands', *Environment Design Guide*, DES 20, Australian Institute of Architects, Melbourne. February.

Romm, J, 1999, *Cool Companies: How the Best Businesses Boost Profits and Productivity by Cutting Greenhouse-Gas Emissions*, Island Press, Washington, DC, USA.

Roodman, DM, and Lenssen, N, 1995, 'A building revolution: How ecology and health concerns are transforming construction', *Worldwatch Paper 124*, Worldwatch Institute, Washington, DC., USA.

Scheer, H, 2004, *The Solar Economy*, Earthscan, London, UK.

Terry A, 2002, 'Indoor air quality in buildings', in Birkeland, J, *Design for Sustainability: A Sourcebook of Eco-logical Solutions*, Earthscan, London, UK. pp. 143–147.

Vale, R, and B, Vale, 2000, *The New Autonomous House: Design and Planning for Sustainability*, Thames and Hudson, New York, USA.

Vale, R, and B, Vale, 2002, 'Autonomous servicing', in Birkeland, J, (ed) *Design for Sustainability: A Sourcebook of Ecological Solutions*, Earthscan, London, UK. pp.182–185.

Velazquez, L, 2008, 'Advantages of Eco-roofs' in *Positive Development: from Vicious Circles to Virtuous Cycles through Built Environment Design*, Earthscan, London, UK. pp.292-3.

Webster-Mannison, M, 2003, 'Cooling Rural Australia', *The Official Journal of Airah*, vol. 2, pg. 22-26.

Weizsacker et al 2010, *Factor 5: Transforming the Global Economy through 80% Improvements in Resource Productivity*, Earthscan, UK.

Weizsacker, E, van, Lovins, A, and Lovins, H, 1997, *Factor 4: Doubling Wealth – Halving Resource Use*, Earthscan, London, UK.

Wrigley, D, 2005, *Making Your Home Sustainable: A Guide to retrofitting*, Scribe Publications, Melbourne.

Zeiler, W, and Boxam, G, 2008, 'Active House, An Alternative Sustainable Building Envelope Concept', *Proceedings of the World Sustainable Building Conference*, SBO8, Melbourne, September.