ECO-RETROFITTING WITH BUILDING INTEGRATED LIVING SYSTEMS

Dr Janis Birkeland [1]

Keywords: *living walls, green roofs, subtropical design, climate change, eco-retrofitting, sustainability, ecosystem services*

Abstract

Building integrated living systems (BILS), such as green roofs and living walls, could mitigate many of the challenges presented by climate change and biodiversity protection. However, few if any such systems have been constructed, and current tools for evaluating them are limited, especially under Australian subtropical conditions. BILS are difficult to assess, because living systems interact with complex, changing and site-specific social and environmental conditions. Our past research in design for eco-services has confirmed the need for better means of assessing the ecological values of BILS - let alone better models for assessing their thermal and hydrological performance. To address this problem, a research project is being developed jointly by researchers at the Central Queensland University (CQ University) and the Queensland University of Technology (QUT), along with industry collaborators. A mathematical model under development at CQ University will be applied and tested to determine its potential for predicting their complex, dynamic behaviour in different contexts. However, the paper focuses on the work at QUT.

The QUT school of design is generating designs for living walls and roofs that provide a range of ecosystem goods and services, or 'eco-services', for a variety of micro-climates and functional contexts. The research at QUT aims to develop appropriate designs, virtual prototypes and quantitative methods for assessing the potential multiple benefits of BILS in subtropical climates. It is anticipated that the CQ University model for predicting thermal behaviour of living systems will provide a platform for the integration of ecological criteria and indicators. QUT will also explore means to predict and measure the value of eco-services provided by the systems, which is still largely uncharted territory. This research is ultimately intended to facilitate the eco-retrofitting of cities to increase natural capital and urban resource security - an essential component of sustainability. The talk will present the latest range of multifunctional, eco-productive living walls, roofs and urban space frames and their eco-services.

Outline

1. Background and overview
   1.1 What is eco-retrofitting?
   1.2 Eco-retrofitting with living systems
2. Benefits of eco-retrofitting
   2.1 Financial benefits
   2.2 Social and environmental benefits
   2.3 Opportunities for eco-retrofitting
3. Implementing eco-retrofitting
   3.1 Impediments
   3.2 Overcoming impediments
   3.3 Need for research in eco-retrofitting
4. Research directions
   4.1 Design and virtual modelling
   4.2 New quantitative models
   4.3 Measuring eco-services
   4.4 Integration with BIM
5. Summary
6. Collaborators and contributors
7. References

---

[1] School of Design, Queensland University of Technology, Brisbane, Australia, janis.birkeland@qut.edu.au

1. Background and overview

Eco-retrofitting with building integrated living systems (BILS) that generate net positive ecological impacts is different from current approaches to green building, and thus requires new design concepts and tools.

1.1 What is eco-retrofitting?

'Retrofitting' can contribute to mitigating climate change, and reducing energy use, water consumption, and carbon dioxide emissions. It can also increase urban air and water quality, and provide myriad other benefits. However, 'eco-retrofitting' means going beyond retrofitting for resource efficiency alone. Eco-retrofitting with BILS implies an eco-logical design approach. By using natural systems to provide multiple functions, greater efficiencies can be achieved through synergies between systems (Romm 1999). After all, it generally costs more if we simply 'add on' energy and water-saving devices to the basic (non-sustainable) building template. Moreover, retrofitting for energy efficiency may save resources, but it can be sub-optimal from an ecological perspective. Eco-retrofitting should aim to improve overall human and environmental health and, ultimately, to expand the ecological base and natural capital. That is, it should to contribute to net Positive Development™ by employing 'design for eco-services' strategies (Birkeland 2005a).

Eco-retrofitting not only means integration at the building scale, but implies a planning strategy that considers whole suburbs, cities and urban infrastructure. Planning for eco-retrofitting from a city-wide or regional perspective suggests the need to actively identify (financially profitable) opportunities for investment in sustainability solutions. Our current tools are designed to mitigate the negative impacts of designs after they are conceived. Instead of trying to attract development to the community simply to fortify the local tax base, planners could identify areas where eco-retrofitting could solve urban problems and increase natural and social capital. This is similar to what Jaime Lerner of Curitiba has called 'urban acupuncture'. That is, revitalizing whole urban areas through small strategic improvements, not just new buildings.

The eco-retrofitting of the built environment (cities, buildings, infrastructure, products and landscapes) is an essential component of sustainability (Birkeland 2003). Some years ago, the OECD warned that a 90 percent reduction in resource flows in a few decades is necessary if we are to achieve a viable level of sustainability. The design of the built environment influences and/or drives most resource flows and environmental impacts. Up to 74% of greenhouse gas emissions has been attributed to cities, and about 40% has been attributed to buildings alone (depending on who measures what, when and where). We have already exceeded the Earth's carrying capacity, and we cannot increase the ecological carrying capacity of wilderness areas. So if civilization is to become sustainable, logically, cities must be re-designed to provide net positive ecological impacts. Ecologically-positive urban environments can only be achieved if we retrofit cities using natural systems.

1.2 Eco-retrofitting with natural systems

Green buildings are becoming more efficient but, overall, they increase net resource flows. Of course, there will always be new buildings. Green buildings are increasing by 20 percent a year in the USA, but new construction is only about 2 percent of the total building stock (Esty and Wilston 2006). Thus, even if all new construction were green, this would have little impact on the growing rate of greenhouse emissions and resource consumption. More fundamentally, we simply cannot replace cities with new ones, due to the material, energy, time and waste that this would entail. It would simply not be ecologically viable. Eco-retrofitting can be achieved with much less land clearing, greenhouse emissions, energy consumption and material flows than new green buildings. Cities could be upgraded to improve human and environmental health more effectively at no extra cost - assuming good research and design. BILS are a potential means to retrofit cities for a range of positive human and environmental benefits, such as biodiversity protection, eco-production, climate change mitigation, ecosystem and public health.

Given that there are millions of homes and buildings in Australia generating environmental costs, BILS could address these cumulative, large-scale problems incrementally - yet simultaneously. Until now, however, retrofitting for energy efficiency is not widely done, let alone. Eco-retrofitting with living systems, this is the case even in subtropical Australia, where cooling and flood mitigation is essential. However, there is a burgeoning interest in living walls and roofs among specialists, and new associations forming, such as Green Roofs Australia. The Brisbane City Council in Queensland, Australia, has incorporated green roofs in its climate change action plan and is encouraging greenery as a response to urban warming. While eco-solutions can be modified for different regions, their sound application depends on site specific climatic, cultural and ecological conditions. Therefore, although some of the concepts are transferrable, this research is focused on subtropical Australia. Before discussing the research, however, the benefits of eco-retroftting will be reviewed.

2. Benefits of eco-retrofitting

BILS not only have the potential to add positive ecological benefits, they offer opportunities for improving in the economic, social and human environment.

2.1 Financial benefits

The financial benefits of green buildings have now been widely canvassed by professional organizations in many countries (Lucuik 2005, RICS 2005, GBCA 2006). Even buildings and retrofits that have involved a substantial amount of research and development have paid back the extra investment within about 10 years, and the payback period is shrinking (Edwards 1998). Arguably the most 'green' building in Australia, the CH2 building in Melbourne, anticipates a five year payback on its huge R&D investment in green features. This means that in six years, the financial savings will be generating a de facto income. Eco-retrofitting is also beginning to receive some attention. Investments in retrofits have been shown to compare favourably with conventional financial investments, such as stocks and bonds (Romm 1999). However, passive solar and living systems are still largely missing from this repertoire. Yet eco-retrofitting can be cheaper than demolition and reconstruction and, from a life cycle and societal perspective, can be even cheaper than doing nothing. Eco-retrofitting can pay for itself through energy savings while reducing externality costs to the public (see Birkeland 2005b). Thus, many Australian cities are beginning to produce information on retrofitting.

Although the costs of retrofitting can be recovered through reduced operating, maintenance, workers' compensation and personnel costs, the 'up-front' costs of eco-retrofitting can also be greatly reduced by eco-logical design. Where resource savings can pay off the loan for the upgrade, a return on investment is virtually assured. According to Romm, US investors can now buy securities in retrofitting. A US research project, for example, found that businesses could expect to achieve a savings of $US 1/sq ft of floor space per month with whole-building retrofits. This amounts to financial benefits for the local community as well, through job creation and economic multiplier effects. Retrofitting a percentage of the urban office stock would have a significant effect on the local economy. For example, the commercial office market in Australia is 19.5 million square metres or about 1 square metre per head of population. A 90 percent reduction in home energy costs is possible through passive solar design (Heede et al 1995). A mere 30 percent reduction in energy usage of half of the detached dwellings in a town could save/earn the town several million dollars a year.

2.2 Social and environmental benefits

New green buildings and towns will not do much to redress the ongoing social, economic or environmental impacts of established cities (eg Dongtan, Dubai). Moreover, large-scale approaches like new towns often manifest a 'social engineering' approach. We should not decide today how people must live in the future, especially since new towns and buildings are still designed to contribute to the urban heat island effect, and arguably contribute to the deterioration of the world's unique cultures and ecosystems. Eco-retrofitting, in contrast, can preserve and increase cultural diversity, while adding ecological and social value. We have talked for decades about new policies, plans and regulations to encourage more sustainable urban form. Meanwhile, we could be eco-retrofitting cities and suburbs. Existing suburbs have adequate space for immediate action to generate positive impacts, such as water cleaning, soil production and more extensive biodiversity habitats on the site than existed before development. This could be undertaken without the social disruption associated with large-scale urban renewal projects, and would not prohibit infill development where appropriate.

There are also thermal, structural, psychological, health, and visual benefits for building occupants. The multiple environmental benefits of living roof and wall systems have been widely canvased (Loh 2008, Velasquez 2008). For example, they:

- Slow down stormwater, reduce the contamination of freshwater sources by runoff, and reduce demands upon stormwater infrastructure.
- Filter, cool and remove heavy metals and nutrients to improve water quality before it reaches coastal or river ecosystems.
- Lower air temperatures in urban areas to reduce the heat island effect and thus reduce convective thunderstorms.
- Reduce dust particles and airborne toxins and improve air circulation around buildings.
- Provide habitat for flora and fauna in general, and for endangered species where appropriate.
- Enable herbs and vegetables to be harvested for local consumption or sale.
- Eliminate glare off roofs and walls to those whose windows overlook the living systems.
- Reduce noise in the building and the surrounding area.
- Increase occupancy rates and rental values through environmental amenity.

- Protect buildings from extreme wind, temperature fluctuations, and ultra violet rays.
- Increase building longevity and reduced maintenance costs.
- Reduce energy bills and costs, while reducing greenhouse gas emissions.

Living roofs and walls can provide natural cooling in subtropical cities, and can potentially provide eco-services such as air and water filtration. BILS could go further, and increase the ecological base and access to the means of survival in cities if passive eco-solutions were integrated with structural systems. The need to retrofit cities for natural security in urban areas has been brought home by recent civil disasters around the world, including floods, earthquakes and terrorism. In fact, thousands of deaths each year are attributed to the urban heat island effect, temperature inversions and floods, exacerbated by past urban design and planning conventions. Roads, wires and pipes can be cut, and should not therefore be designed as exclusive 'lifelines' for residents. Large-scale urban systems that make their populations entirely dependent on centralized agricultural, transport and energy systems are not very secure or resilient.

2.3 Opportunities for eco-retrofitting

There are many opportunities to improve urban conditions at a net financial, social and environmental gain. For example, in most cities there is a growing supply of aged or underused buildings that are in need of basic maintenance anyway. The refurbishment (as opposed to eco-retrofitting) industry, with its huge material consumption, has greater material flows than new construction in some places. The need for refurbishment is partly because buildings are designed on the basis of 'planned obsolescence'. In fact, large commercial buildings are often designed to be refurbished about every 15 years or so, and minor renovations are undertaken every few years to attract or accommodate new tenants (see Storey 2002). Some buildings even have 'facadectomies' where the façade is replaced just to attract different tenants and higher rents. In other words, while ostensibly market-driven, buildings are not designed to adapt to market demand, let alone changing social needs. This problem could be converted into an opportunity. Eco-retrofitting for adaptability, disassembly and 'compostability' would make these changes far less costly.

Currently, our design tools currently get in the way of eco-retrofitting. Not only do most green building guidelines and assessment tools focus on new buildings, they do not count the full ecological costs of conventional renovations, such as the resource flows and 'embodied waste' in demolition (let alone construction). Little regard has been paid to the (often toxic) waste, impacts on indoor air quality, and other sustainability issues associated with the massive resource flows in building construction and conventional fit-outs. When tools *do* count the costs, they focus on adverse health effects or negative impacts. Yet evidence is mounting that good air quality, lighting and views of gardens can measurably improve occupant health as well as reduce illnesses. There are huge opportunities to turn these ongoing renovations from a negative to a positive force by the use of natural systems. Health and safety are a cost effective investment over the long term. With good design, living walls and roofs can increase life quality, by creating a more interesting, healthy and diverse urban environment.

3. Implementing eco-retrofitting

Our current development systems and design norms and tools impede eco-retrofitting, but there are many institutional and technical ways of addressing these problems.

3.1 Impediments

The resistance to integrating natural systems with the built environment are systemic, such as entrenched perceptions about the incompatibility of natural and urban systems, the nature of industrial (one-size-fits-all) development, and institutional inertia. Some reasons for the lack of uptake of BILS include:

- Lack of living wall and roof demonstration projects
- The initial design and construction costs
- The lack of incentives for experimentation in eco-logical design
- Lack of awareness of passive solar design in general
- The focus on reducing impacts instead of health improvements.
- Inadequacy of codes and regulations in supporting urban ecology
- Lack of government support, such as loans for living systems
- Lack of procurement systems to ensure quality components
- Rating tools that serve to lock in conventional (non-sustainable) building typologies
- Risk aversion and the perceived lack of client demand by developers
- Scepticism about the cost and value of living systems in urban areas
- Our inability to comprehend the value of living things with numerical representations.

3.2 Overcoming impediments

Although eco-retrofitting could save money and resources over time, the market does not reward ecologically and socially positive development. It only rewards resource efficiency, and only then where there are no perverse subsidies. Many ways of addressing the intellectual and institutional resistance to eco-retrofitting have been canvassed elsewhere (see Birkeland 2008). The solutions may be less about creating incentives than in removing systemic biases that favour industrial norms. Some solutions include:

- Rating systems: Currently, building rating tools do not provide credits for living walls and roofs. Credits could simply be given for the square metres of 'ecological space' or area allocated to ecosystem goods, services and self-maintenance. Rates could be reduced in proportion to a building's contribution of ecological space. Also, councils could legislate for mandatory disclosure of the building's energy rating to potential buyers or renters, as is done in Canberra, Australia. Favourable mortgage rate programs already exist in some places for new energy efficient homes. These could be modified to explicitly encourage eco-retrofits.
- Full cost pricing: Despite years of market-based strategies, perverse subsidies remain. There has been little progress toward full cost pricing. If we paid the full cost of resources, the incentives for ecological design would be enormous. However, our environmental impact assessments seldom, if ever, count the opportunity costs of using resources unnecessarily, let alone the replacement cost of resources. Nor do they account for the time it takes ecosystems to recover after resource extraction (ie 'ecological waste'). Full cost pricing would still not address the problem of up-front costs that is involved in eco-retrofitting.
- Performance contracting: A way to counter the upfront cost of eco-retrofitting is performance contracting. Here, the service providers themselves meet the costs of the retrofit, and recoup their costs and profits through the resource savings over time (see www.aepca.asn.au). Because the construction costs are paid for from the operational costs of the building, this approach is in a sense self-funding, generates its own clients, and makes money by doing good (Birkeland 1995). However, when undertaken, the market tendency has been to 'cherry pick' easy lighting upgrades for profit, without rolling over these funds into programs to tackle whole building retrofits.
- Community government partnerships: Government action could bring about the transformation to more sustainable cities more quickly through up-skilling and education in eco-retrofitting. That is, instead of mitigating problems after a design proposal is offered for a particular site, governments could provide the analyses to determine the best land uses from an ecological and social perspective. 'Direct action', in this context, means implementing physical design solutions - as opposed to indirect incentive systems which can have unintended consequences in complex systems (see Birkeland 2002a). Public-private-community partnerships would ensure that priority areas are targeted first (see 'hierarchy of eco-innovations' in Birkeland 2008).
- Planning incentives: Councils can also create development incentives, such as allowing the addition of a second floor dwelling unit if, and only if, the addition converts both units into 'resource autonomous' dwellings or better (Birkeland and Schooneveldt 2002). For example, in single-storey suburbs, second storey units could be permitted if both dwellings were eco-retrofitted (eg for passive solar heating, cooling and ventilating using living walls and roofs combined with solar stacks and photovoltaic cells, etc). This would provide owners the financial benefits of both rental income and increased capital value while reducing the demand on infrastructure. It would also increase suburban density with little increase in land coverage, and without disrupting local communities. In line with what some progressive city councils are doing already, a reduction in stormwater management fees can be given to building owners who reduce runoff through living roofs and walls. Permits for renovations or new developments can be 'fast tracked' to compensate for positive improvements to the urban area (Velasquez, 2008).

3.3 Need for research in eco-retrofitting

The dominant assumption has been that living systems would represent added costs with only 'intangible' benefits for the public (not the investors). Developers would be hesitant to exploit the potential value of living walls for their bottom line, unless these can be easily predicted and verified. As yet, there are few if any models for assessing the multiple benefits of living walls in subtropical Australia (Stav 2008). Therefore, this project was conceived to develop and evaluate a model for predicting the capacity of living roofs and walls to provide multiple functions. These include, among other things, reducing heat gain in buildings, reducing energy for cooling buildings, increasing the thermal comfort of the occupants, and increasing ecosystem goods and services in subtropical urban contexts. The project will also develop sustainability indicators and design guidelines for living walls and roofs to enable rapid adoption by the Australian design and construction industries.

The project builds on work already undertaken at QUT to foster ecologically Positive Development through built environment design. In contrast to 'regenerative' design, Positive Development means increasing ecological carrying capacity and natural and social capital beyond what existed on site before any development occurred. Designing cities to reverse the negative impacts of past designs, and to generate net positive ecological impacts, would entail new approaches to design, construction and assessment. This requires the integration of engineering, ecology and design. Therefore, the research team includes researchers with expertise in building performance simulation and thermo-fluid mechanics at CQ University, and sustainable architecture, engineering, and digital tools at QUT (see collaborators below).

Given the lack of experience with BILS, let alone means to assess urban eco-services, exemplars showing how to eco-retrofit cities will facilitate transfer, experimentation and adoption of living systems. Although ecological design is necessarily site-specific, generic prototypes for eco-retrofitting with BILS are necessary, to show how they can be assimilated into existing structures and processes. These concepts include 'green scaffolding', which are frames that wrap an ecosystem around existing buildings to increase their life span, functionality and eco-productivity (Birkeland 2008). Such frames would vary with each situation, but some could support mini-ecospheres that provide a wide range of ecosystem services and biodiversity habitats, as well as heating, cooling and ventilating functions. New prototypical living systems for eco-retrofitting are being virtually modelled to optimise their designs for different sites, applications, functions and contexts. It is intended that the new design concepts and measurement tools will enable policy makers and developers to understand the multiple values of eco-retrofitting subtropical cities with natural systems that cool air, treat water, produce oxygen, remove particulates, protect biodiversity and improve health.

4. Research directions

Our existing rating tools do not foster design for eco-services, and are neutral in encouraging passive solar design. Therefore, the new designs, measurement methods, ground-truthing will require integration with building assessment and modelling tools.

4.1 Design and virtual modelling

At this stage, assessment tools can only enable users to design 'less unsustainable' buildings. They do not aid designers in creating things that have never existed, such as net positive or sustainable buildings. This research will form the groundwork for designing and optimizing means of increasing the eco-services of living systems to generate net positive ecological impacts. The new design alternatives for BILS will be virtually modelled to optimize performance (to be presented in the talk). The designs will be analysed using LCADesign by Ecquate Pty Ltd. Then, the theoretical and quantitative models will be verified by actual field trials. Assuming adequate resources, industry partners, Sala Homes Group and Affordable Quality Homes, plan to construct optimized roof and wall systems respectively in demonstration homes. They will provide access to the testing facilities throughout the research period.

LCADesign software is arguably the most significant building assessment tool developed so far. Its aim is to provide practitioners a precise calculator of the ecological impacts of buildings automatically off advanced CAD building information models (BIMs) in design, operation, refurbishment and fit-out. Its unique combination of features could deliver a significant reduction of negative environmental impacts. LCADesign will be used to compare and contrast the performance of a range of BILS considering multiple variables (eg price, ecosystem and human health, ozone depletion, climate change, eutrophication and water use). A life cycle inventory of the supply chain and design element operation in case studies will be developed for a full cradle-to-cradle impact assessment of these living systems. In turn, the new measurement concepts and models will be integrated into LCADesign.

4.2 New quantitative models

The joint CQ University + QUT project is also designed to find appropriate quantitative methods and models for assessing BILS. Researchers at CQ University (Khan, Rasul, and Chowdhury), envisage a new computational model of heat transfer processes in living systems. This model will account for long wave and short wave radiative exchange within the plant canopy, which affects convective heat transfer, evapotranspiration from the soil and plants, and heat conduction (and storage) in the soil layer. Their proposed model will consider moisture balance that allows for precipitation, irrigation and moisture transport between two soil layers, soil and plant canopy energy balance, soil surface and foliage temperature to extract heat flux information for the energy balance. A parametric study will be performed by CQ University in order to evaluate the main system characteristics that affect the performance of BILS for cooling and eco-production in for subtropical cities. The analysis will identify the most significant parameters affecting the performance of living systems. Controlled variables (solar radiation, air temperature, air relative humidity, cooling capacity and soil water content) will be modified one at a time to study how they affect the soil conductivity, evapotranspiration rate, plant thermal resistant, plant optical properties, and long wave radiation. The end result should be a set of simultaneous equations for temperature, soil surface and foliage temperature and other variables. It will also determine the savings of energy consumption and cooling load in different types of living systems. Information on this work can be sought from m.rasul@cqu.edu.au (as it is not the author's area).

4.3 Measuring eco-services

Algorithms for assessing the ecological values of living systems, as well as thermal and hydrological performance, are also needed. As explained by Yael Stav (2008), the quantitative measurements of the performance of living walls are complex due to the changing interactions between living walls and their environment. Site-specific variables, such as building orientation, layout and thermal capacity, greatly affect measurements of thermal performance, let alone ecological variables. Roof-to-wall and window-to-wall ratios influence rates of stormwater retention and filtration, air quality improvement, food production and wildlife habitat restoration, as well as thermal performance. Temperature, humidity, wind, pollution, elevation, radiation and climate all influence the species of plants and animals that can survive. Given this complex interaction, Stav argues that we must rely on field experimentation in the first instance. An advantage of BILS is that design failure does not require demolition. Instead, the armatures for BILS merely require modification of their passive systems, and better use of horticulture, biology and other sciences. In fact, living roofs and walls in urban areas could become laboratories for a new field of urban environmental management and biodiversity conservation.

In addition to understanding how the design of BILS can influence the communities of plants and animals within them, it is important to measure urban ecosystems and eco-services. Thus the project entails measuring the positive eco-services provided by living systems as well as physical functions. The economic values of eco-services can be measured in many ways. Among the simplest measure is to assess the costs avoided, or the savings gained by reduced resource costs, such as wastewater and stormwater treatment avoided, the reduced need for air conditioning, and the reduction in the urban heat island effect. However, these methods do not fully respect the intrinsic value of ecosystems. Estimating the value of ecosystems to the wider life support system (eg food chain) is another matter. While to some, urban ecosystems still seem superfluous, the dominoe effect of ecosystem collapse can be catastrophic. The value of the life support system is infinite, and it could be said that a regional or global ecosystem is only as viable as its weakest local ecosystem. Conventional measurement methods (that reduce everything to energy or money) fail to deal adequately with this reality (Heal 2002).

4.4 Integration with BIM (building integrated modelling)

For ecological values to be incorporated in design, they need to be integrated with digital design tools. The construction industry is moving rapidly towards building information modelling (BIM). BIM uses 3D modelling to produce drawings that embed information on construction components, so that the participants in the construction process can share data, and exchange information between software systems. This can expose errors and conflicts such as those between plumbing and electricity systems. LCADesign uses a 3D building model as the basis for its eco-efficiency assessment of buildings. The user enters specific data to the standard CAD model and then exports this information into LCADesign for analysis. Various substitutions can be made within LCADesign to improve the efficiency of the design. A range of alternative components can be explored in a few hours. Currently, the basic areas of sustainability analysis, such as analysing embodied energy, greenhouse gas emissions, biodiversity, health, and so on, are not well served by BIM or available data (Drogemuller and Frazer 2008). This research should contribute to the greening of BIM as it in turn increases its influence on the design process.

The value of living systems also needs to be incorporated in building rating tools, which increasingly dominate built environment decision making. There are many such tools for predicting the performance of buildings (LEED, BREEAM, Green Star, NABERS, etc) and homes (BASIX, Ecohomes, NatHERS, etc). However, they reputedly do not work well in warm humid climates and do not yet encourage the use of living systems. These tools have treated the relative reduction of impacts on the environment as a 'gain'. Yet they do little if anything to increase the ecological base and natural security of cities. They do not even measure positive improvements to ecosystem size and resilience. They only count reductions relative to what might otherwise have occurred. This omission can disciminate against attempts to create positive ecological impacts in built environment design. Many designers will not think of trying to include (even free) positive impacts if these are not assessed. Since rating tools are here to stay, it is hoped that they can be made relevant to ecologically positive design.

5. Summary

The research aims to integrates building science, design and ecology. The basic components of our work are to:

- Design of a range of innovative living roofs and walls, to be optimized by the virtual prototyping of, for example, thermal, energy and ecological factors, and selecting designs for on-ground testing (QUT).
- Develop a mathematical model which provides a representation of the complex, dynamic behaviour of living systems in terms of multiple criteria (CQ University).
- Conduct a comparative analysis of building performance with and without the living system on the structures provided by industry partners (CQ University).
- Develop means of measuring the ecological value of eco-services that can be provided by specific prototypes of living walls and roofs (QUT and CQ University).
- Integrate the concepts into a building performance tool to assist design engineers and architects, using LCADesign (Ecquate Pty Ltd)
- Develop indicators and guidelines for incorporating living and renewable energy systems into new and retrofitted buildings (QUT).

6. Collaborators and contributors

Current research team members include: Mohammed Rasul, Masud Khan and Ashfaque Chowdhury of CQ University; Richard Brown, Susan Loh, Yael Stav, and David Nielsen of QUT. Current industry collaborators include: Sala Homes Group, Ecquate Pty Ltd, the Centre for Subtropical Design, the Australian National Biocentre Inc, and Affordable Quality Homes. None of these organizations or individuals are responsible for errors in this paper. This paper should be seen as an invitation for those working in this area to collaborate with us to develop means to eco-retrofitting with living systems.

7. References

- Birkeland, J. 1995, 'Rethinking Pollution', *Turning Growth into ESD - Economically, EIA National Conference*, Brisbane, 26-27 October, Brisbane.
- Birkeland, J. 2002a, 'Legislative Environmental Controls', in *Design for sustainability: A Sourcebook of Eco-logical design Solutions*, Birkeland, ed., Earthscan, UK, pp. 210-214.
- Birkeland J. and J. Schooneveldt 2002b, *ACT Sustainability Audit: A Material Flows Analysis of the Residential Sector of Canberra*, Report for PALM, Sustainability Science Team, Canberra.
- Birkeland, J. 2003, 'Beyond Zero Waste', *Societies for a Sustainable Future*, Third UKM-UC International Conference 14-15 April, Canberra.
- Birkeland, J. 2005a, 'Design for Ecosystem Services: A New Paradigm for Eco-design', SB05 Tokyo *Action for Sustainability: The World Sustainable Building Conference*, September 2005.
- Birkeland, J. 2005b, 'The Case for Eco-Retrofitting', *Solar Progress*, pp. 7-9, Vol 26, No 2.
- Birkeland, J. 2008, *Positive Development: From Vicious Circles to Virtuous Cycles through Built Environment Design*, Earthscan, London, UK.
- Drogemuller, R and J Frazer, 2008, 'Digital Modelling for Sustainability', in *Positive Development: From Vicious Circles to Virtuous Cycles through Built Environment Design*, Birkeland, ed., Earthscan, London, UK. p. 307.
- Edwards, B. 1998, *Green Buildings Pay*, Spon Press, London.
- Esty, D. C. and A. S. Wilston (2006) *Green to Gold: How Smart Companies Use Environmental Strategy to Innovate, Create Value and Build Competitive Advantage*, Yale University Press, New Haven, CT, and London.
- Green Building Council Australia, 2006, *The Dollars and Sense of Green Buildings: Building the Business Case for Green Commercial Buildings in Australia*, GBCA, Australia.
- Heal, G. 2000, *Nature and the Marketplace: Capturing the Value of Ecosystem Services*, Island Press, Wash, DC.
- Heede, R. et al 1995, *Homemade Money*, Rocky Mountain Institute with Brick House Publishing Company, NH, USA.
- Loh, S. 2008, 'Living Walls - a Way to Green the Built Environment', *BEDP Environment Design Guide*, ACT, Australia, p. 1-7.
- Lucuik, M, 2005, *A Business Case for Green Buildings in Canada*. http://www.cagbc.org/uploads.
- RICS, 2005, *Green Value*, *Green Buildings, Growing Assets*, UK. http://www.bluewildernessgroup.com.
- Romm, J. 1999, *Cool Companies: How the Best Businesses Boost Profits and Productivity by Cutting Greenhouse-Gas Emissions*, Island Press, Wash. DC. p. 55.
- Stav, Y. 2008, 'Measuring Living Wall Performance', in Birkeland J. *Positive Development: From Vicious Circles to Virtuous Cycles through Built Environment Design*, Earthscan, London, UK, p. 332.
- Storey, J. 2002, 'Designing for Durability', in J. Birkeland, *Design for sustainability: A Sourcebook of Eco-logical design Solutions*, Earthscan, UK, pp. 46-49.

- Velazquez, L. 2008, ‘Advantages of Eco-roofs’ in Birkeland J. *Positive Development: From Vicious Circles to Virtuous Cycles through Built Environment Design*, Earthscan, London, UK, p. 292.