# THE WINSTON CHURCHILL MEMORIAL TRUST OF AUSTRALIA

Report by **GRAEME HOPKINS** **2005 Churchill Fellow**

**To study the latest information, technology and projects featuring elements that make up a 'bushtop landscape', which recreates particular ecosystems on the top of buildings and on vertical walls.**

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Signed Dated

**Graeme Hopkins** **7 September 2006**

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# Introduction

Cities around the world are becoming denser, with less green space, landscape areas and permeable surfaces. Even Adelaide, with its extensive parkland system, is under pressure from intensive human intervention and interaction, and from the spread of feral flora and fauna species. One way of creating more natural environment within the city centre is to use the rooftops and vertical walls of buildings.

For several years now I have been extending this concept to encompass a more complex ecosystem - bushtop landscapes. This recreates elements that make up a particular ecosystem, such as the Adelaide plains, on top of city buildings to provide habitats for plants, animals, birds and insects to breed and to pass through the city. Vertical green walls, or living walls, can connect rooftops to the ground and create even more habitat opportunities for the appropriate native fauna.

This fellowship has given me the opportunity to catch up with the latest technologies and innovations, and to compare and contrast ideas and design approaches with other overseas professionals who share my commitment within this field. This fellowship was a career highlight for me. Throughout the trip I visited 60 projects and formally met with more than 20 people. I would like to thank all the people I met during this fellowship for their generous time and for sharing their information and experiences with me.

Here in Australia I would particularly like to thank Professor Chris Daniels, Dr Susan Shannon and Ms Trixie Smith for their ongoing support, and Christine Goodwin for all the support and work that went into making this fellowship a success.

*Acros Building, Fukuoka, Japan*

# Executive Summary

## Graeme Hopkins

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During my fellowship there were many highlights and people I met of great value to my ongoing research, but the following stand out in particular:

- Attending a Biodiversity Workshop in Boston at the Fourth Annual Green Roofs for Healthy Cities Conference
- Having access to study construction documentation of Millennium Park, Chicago
- Discovering living walls and construction techniques in Toronto and Japan
- Visiting a living and cultural ecosystem at Roppongi Hills in Japan, with its landscape, including a 6th floor rice paddy, being an integral part of the building's earthquake design
- Climbing the stepped rooftops of the Acros Building in Fukuoka from ground level to the 8th floor rooftop
- Meeting with leaders in the field and discussing the latest research and development in Singapore and Kuala Lumpur

The major lessons and conclusions learned in this fellowship:

- Commitment to continue research and development into bushtop ecosystems and creating aerial corridors, and using living walls as ground connectors to increase biodiversity and open space in dense urban areas
- The need for basic research through demonstration sites to establish localised performance information on both rooftops and living walls
- The need for government incentive programmes to develop greener buildings using rooftops and living walls to reduce energy consumption and heat island effect to the local environment

How I will disseminate and implement what I have learned:

- Promotion to target interest groups such as Architects, Landscape Architects, Planners, Urban Designers and Building Owners through lectures and articles
- Initiating research and on site information gathering for the thermal insulation performance of bushtops and living walls in Adelaide
- Initiating State and Local government policy processes for bushtops and living walls as part of Adelaide's sustainable development agenda and planning policy

# Programme

This programme includes the people, organisations and projects visited as part of the fellowship, undertaken from May to July 2006.

**USA** May 9 – 29
**Boston** May 9 - 15
Fourth Annual Greening Rooftops for Sustainable Communities Conference
Certificated and accredited workshop/courses (Green Roofs for Healthy Cities)

- Design for Biodiversity – Dr Stephan Brenneisen of the University of Applied Sciences Wadenswil, and Paul Kephart and Brent Bucknum of Rana Creek Habitat Restoration and Living Architecture
- Planning Green Roof Infrastructure
- Green Roof Design 101 Introductory Course

**New York** May 15 – 20
Mathews Neilsen Landscape Architects – Signe Neilsen and Runit Chhaya
Irish Hunger Memorial – site visit
Diana Balmori Associates – Martha Desbiens (Rooftop Project Manager)
HighLine – Katie Loral (Project Officer)

**Chicago** May 20 -27
Millennium Park – site visit
City of Chicago – Michael Berkshire – Green Project Administrator
Terry Guen and Associates Landscape Architects – Terry Guen
Lincoln Park Zoo Flamingo House – site visit
Peggy Notebaert Nature Museum – site visit
Centre for Green Technology - site visit and tour
70W Monroe St. Plaza – site visit

**CANADA** May 29 – June 7
**Toronto**
Toronto City Hall – demonstration project – site visit
Sheraton Hotel – site visit
Ryerson University George Vari Engineering and Computing Centre – site visit
City of Toronto – Jane Welch – Senior Project Officer
Mountain Equipment Store – David Robinson – site visit
Urbanspace Property Group – Beth Anne Currie (Environment, Health and Safety Coordinator) 401 Richmond St West, JAS Robertson building, Spadina Ave –site visit
Perennial Gardens Corp. Design and Builders – Terry McGlade – site visit
Residential rooftops at Euclid St., new architect's house and Toronto Botanic Gardens new administration buildings
Green Roofs for Health Cities – Steven Peck
Canada Life, internal living wall – site visit

**SPAIN** June 9 – 12
**Barcelona**
Adjoining courtyard roof to Casa Batllo (Gaudi designed house) – site visit
Park Guell – site visit
Jardi Botanic entry buildings – site visit

**JAPAN** June 13 – 5 July
**Tokyo - Roppongi area**
Vertical living walls on building façades and building hoardings – site visit
**Tokyo - Roppongi Hills**
Keyakizaka complex roof top – site visit and tour
Residential and Commercial Building complex - site visit
Roku Roku Plaza – site visit

**Tokyo**
St Lukes International Hospital – site visit
Tokyo International Forum – site visit
Tokyo Station Entry – site visit

**Kyoto**
Garden of Fine Art - architect Tadao Ando – site visit
Daimaru Department Store – site visit
The Cube – Kyoto Railway Station – site visit
Byodo-in Temple Museum – site visit

**Osaka**
Hanshin Department Store – site visit
Umeda Sky Building – site visit
Osaka Municipal Central Gymnasium – site visit
Umeda Daibiru (Osaka Garden City) – site visit
The Museum of Art Osaka – site visit
Sogo Department Store – site visit

**Awaji Yumebutai**
International Conference Centre – site visit
The Westin Awaji Island Resort – site visit
Water Plaza of the Shell and Temple – site visit
Awaji Island Akashi Kaikyo Park – site visit
Water Temple – site visit

**Takamatsu**
Symbol Tower / Maritime Plaza and Wharf Piers – site visit

**Naoshima Island**
Benesse House Museum – site visit
Chichu Art Museum – site visit

**Fukuoka**
Acros Fukuoka Building – site visit
Hyatt Fukuoka – site visit
Canal City – site visit
Island City Central Park Gringrin – site visit
Momochi Seaside Park – site visit

**SINGAPORE** 6 – 14 July and 21 – 22 July
Singapore National Library – site visit
Esplanade Theater Complex – site visit
National Parks Botanic Garden – Dr Puay Yok Tan and site visit
Housing Development Board – Bee Choo Tay senior landscape architect
Envirospace consultants – Richard Tan – meeting and site visit
Subaru Singapore – site visit
National University of Singapore –Associate Professor Nyuk Hien Wong, Yu Chen PhD Candidate, Steve Kardinal Jusuf PhD Candidate
Singapore Night Safari – site visit
Water Place residential complex – site visit

**MALAYSIA** 14 – 18 July
**Kuala Lumpur**
Federal Hotel podium – site visit
Petronas Twin Towers – site visit
Landskap and Taman Malaysia 2006 Garden Festival – site visit
T.R. Hamzah and Yeang Architects – Dr Ken Yeang

*Graeme Hopkins with Dr Ken Yeang in Kuala Lumpur*

## Green Roofs

Green roofs are a series of layers of living vegetation growing in substrate on top of buildings, either on large multi-storey or small domestic residential dwellings. These green roofs can be incorporated into new building projects, or retro-fitted to existing buildings provided the structure of the building is suitable.

There are many benefits resulting from the installation of green roofs, including the management of stormwater and improved water quality by retaining and filtering rainwater through the plants' soil and root uptake zone. Green roofs can be designed to reduce rainfall runoff to zero, but typically reduce runoff by 50%.

They also act as bio-filtration devices that remove pollutants such as cadmium, copper, lead and nitrogen. The reduction of the 'heat island effect' in a city can be easily up to five degrees with the introduction of vegetation. Green roofs can reduce the effect of carbon dioxide by increasing the carbon dioxide/oxygen exchange through the process of photosynthesis. Air pollution is reduced by removing airborne particulates from the air. It has been calculated that $1m^2$ of grass roof removes 0.2kg every year.

One of the major benefits is the reduction of heating and cooling loads within the building, with figures of 10% for multi storey and 20% for single storey buildings. In addition, roofs with built-up membrane systems can have a life expectancy at least twice and usually three times longer than usual, by protection from mechanical damage, UV-rays, hail and extreme temperature differences. There is evidence that real estate values increase around green roofs, especially for those looking down onto the green roof. Green roofs provide for greater habitat and biodiversity opportunities. In particular various bird species and invertebrates can thrive in habitats featuring a sustainable variety of plants.

## Living Walls

Building façades are under permanent environmental influences, such as sun and acid rain, which age and can ultimately destroy them. Vertical green walls or living walls can protect façades and offer similar benefits to the installation of a green roof.

Living walls or green façades are relatively new in contemporary urban ecology terms, only being developed since the 1980s in Europe. However the concept of greening building façades has been used throughout history, on individual buildings.

There are two major benefits for using living walls: ecological, and visual.

**Ecological benefits**

- Biomass production
- Dust reduction
- Heavy metal reduction
- Thermal insulation
- Noise reduction
- Biodiversity
- Evaporation cooling
- Food production

**Visual benefits**

- Streetscape
- Building façades

*Awaji National Park entry, Japan*


*Carparking station, Toronto*

# Types of Green Roofs and Living Walls

**Green Roofs**
There are various types of green roofs and a commonly adopted classification is based on the thickness of the substrate. I have developed an extra classification for major landscapes that establishes a new assumed ground plane such as podium/plazas, over roads and railways, called an 'elevated landscape'.

There are four major classifications for green roofs:

- **<u>Extensive</u>** – depth of substrate 150mm or less, lightweight system with low prostrate vegetation, and often inaccessible

*Extensive system at 401 Richmond Street West, Toronto*

- **<u>Semi-intensive</u>** – depth of substrate above and below 150mm, combines the best features of extensive and intensive, partially accessible and has greater plant diversity

*Mountain Equipment Store in Toronto*

- **<u>Intensive</u>** – depth of substrate more than 150mm, usually accessible for greater human use, best insulation properties and stormwater management and greater biodiversity potential

*Westin Awaji Resort, Japan*

- **<u>Elevated landscape</u>** – 600mm or greater and creating a new ground plane, the greatest potential for bushtops with its biodiversity and topography shaping potential, and has the same insulation and stormwater management potential as the existing ground surface

*Millennium Park, Chicago*

**Living Walls**
Living walls are classified into two basic types:

- Green façades with climbers
- Living walls – active, passive and wildlife habitats

<u>Green Façades</u>
These walls feature vertical structure systems that support climbers on stainless steel cables, webbing or metal grids, and the climbers grow up from planters or in-ground planting.

*Green façade on Hanshin department store, Osaka, Japan*

<u>Living Walls</u>
Living walls are where plants are grown onto a vertical system, based on principles of hydroponics for moisture and nutrients.

An Active Living Wall is where plants are rooted into fabric pockets or pre-vegetated panels supported by a vertical frame, part of a 'vegetated building envelope system' or green cladding.

*Active living wall in Roppongi, Tokyo*

A Passive Living Wall is where the plants are used as a bio-filtration of VOC's (volatile organic compounds) by drawing air through the vertical system, such as the BioWall system in Canada.

*Passive living wall in JAS Robertson building, Toronto*

Vertical Habitat is a system where layers of plantings are arranged in a manner to create a sheltered habitat for not only birds but for insects, spiders and other small animals.

*Vertical habitat at Singapore Botanical Gardens*

# Bushtops

This fellowship was awarded to look at Bushtop green roofs and living walls, and the elements that make up various types of green roofs and living walls that can be incorporated into Bushtop ecosystems.

It is common in other parts of the world to describe Bushtops as an evolution of the eco-roof or living roof. The Bushtop goes further in that it proposes to establish not just the physical structure of habitats or ecosystems, but also to introduce the relevant animal species into this type of green roof from the early design and implementation stages.

I attended a Biodiversity Workshop at the Fourth Annual Greening Roofs for Sustainable Communities Conference in Boston in May 2006, and it was evident that the work and research by two organisations were similar to our Australian Bushtop project. The first was Dr Stephan Brenneisen of the University of Applied Science Wadenswil Switzerland, and the second, Paul Kephart and Brent Bucknum of Rana Creek Habitat Restoration and Living Architecture USA. Each of these has produced research findings that support our Bushtop outcomes, although through somewhat different avenues of research.

The research by Dr Stephan Brenneisen was of particular interest as they were using thin extensive inaccessible green roofs which are common in Basel, Switzerland and North America. These extensive green roofs do not have deep soil layers, therefore in extreme dry periods plants cannot draw up groundwater. Similarly, ground-dwelling animals have little opportunity to retreat into lower substrate cooler and damper zones. On rooftops, as in all ecosystems, water is the main factor and essential for all processes of life.

In supporting biodiversity on green roofs you need to look at comparable habitats in nature or near-natural situations. Some of the key factors are:

- lack of water in hot dry periods
- slope of the roof creating dryer areas because of runoff of the substrate slope in wet periods
- limited space to establish permanent populations
- some species not finding it easy to reach the roofs – no connection to the ground
- lack of nutrients for some species in some substrate types
- substrate conditions and thickness

Many of these European and North American extensive green roofs were not originally designed as ‘living biodiversity’ roofs but were colonized by spontaneous development from airborne seeds and animals. This opportunistic colonisation of ecosystems will behave like any other ecosystem once established, requiring the same key factors to survive.

Also these researchers found that the deeper the substrate is, the greater the vegetation biodiversity, and this also refers to the animal biodiversity. This research is in its infancy and its main target animal groups for green roofs are insects (bees, butterflies, grasshoppers etc.), spiders, birds, and lizards.  It has been shown that a large number of mobile organisms such as spiders, beetles and bee species do colonise green roofs and can establish themselves systematically.

Studies have revealed that a landscape surface structure using a substrate of local soil leads to optimized habitat conditions.  Some species need small, permanently vegetated areas and others need large stones as an important part of their habitat. The topography of the substrate is important to the quality of habitat, as a levelled substrate produces uniform conditions and increasingly dense vegetation cover whereby more competitive species drive out less competitive species.

The habitat quality can be improved by varying the substrate thickness by introducing small mounds or hillocks. This creates micro climates and small changes in habitat conditions.  Also by installing habitat features like dead branches for bird perches will improve the habitat for birds.  It is important to introduce small islands of original ecosystems into the constructed habitat to allow these new ecosystems to develop out from these islands as well as allowing random selection. This research was supported by many projects I visited during this fellowship, such as Chicago City Hall which has bee hive boxes located on the green roof some eight floors above the street level.

*Bee hives on Chicago City Hall rooftop*

*Goose on Flamingo House, Lincoln Park Zoo*

Also in Chicago at the Lincoln Park Zoo I photographed a goose nesting on the extensive green roof of the Flamingo House.  At Chicago's Centre for Green Technology water birds started nesting in the extensive green roof until the wetland was built next to the building and then during the following breeding season they moved into the wetland.

In Toronto at the Mountain Equipment Store's extensive green roof three floors high, ducks regularly nested and successfully raise their young until they were disturbed by the regular guided tours of this green roof and building.  In New York, Diana Balmori Associates have discovered that some green roofs have suffered from particular plants being damaged and removed by birds as a food source. This indicates that green roofs are a vital part of the ecosystems and that designers need to fully understand what elements they are designing into their green roofs because they can become part of a larger ecosystem.

The research by Paul Kephart and Brent Bucknum and their Rana Creek group provides some interesting information. For example, the use of different vegetation for various parts or aspects of the green roof according to the biophysical requirements results in an improved variety of vegetation and richer ecosystems. This is more evident on sloping roofs whereby the processes in the substrate as well as the vegetation selection were critical for various parts of the slope. So, at the bottom of the slope wetland type planting should be used because of the greater amount of groundwater collection, and towards the top of the slope plants with greater dryness tolerance can be used.

But of greatest interest to the Bushtop project was the bioregional biodiversity design approach of these researchers. This is related to the green networks or greenways that interconnect natural or vegetated open space in the midst of heavily developed or exploited areas. In terms of urban ecology, both resident and migratory biota utilize and are often dependent on such interlinked networks. Green roofs, although strictly speaking not ‘corridors’, can nevertheless serve as essential ‘stepping-stone habitats’ in a highly fragmented urban mix.  In fact it has been argued that a close mosaic of stepping stone habitat patches may be as effective as a continuous strip in allowing many species to permeate the whole area.

Green roofs also serve as refuges or stepping stones for ‘metapopulations’, (a system of local populations linked by dispersal). Green roofs acting as corridors or stepping stones can provide a ‘rescue effect’ and allow small populations a higher probability of persistence than if they were isolated. Rana Creek is currently working on three living roofs or bushtops projects that fall within the range of the threatened Bay Checkerspot Butterfly’s metapopulation zone.

The metapopulation theory, developed by Ehrlich, states that ‘The species in metapopulation are usually thought of as having interdependent extinction and colonization processes, where individual populations may “wink out” (go extinct) and later “wink on” again (be recolonized from another population that is still extant). (Ehrlich 1975)

Rana Creek’s three projects incorporate host plants and nectar sources for the Bay Checkerspot Butterfly. In normal circumstances these living roofs would not be thought to support viable populations, however it was found that some current habitat patches were as small as 0.1ha and the whole metapopulation is limited to a total of 1ha. Thus these living roofs can play a vital role in the survival of this species.

The above methodology (metapopulation theory) is what the Bushtop project is based upon.  It was interesting to see the Rana Creek group working on similar concepts to those I am proposing for Bushtops in the Adelaide CBD.  My proposal is to create a series of Bushtop living roofs (habitats and ecosystems) throughout the CBD reflecting the original migrational corridor patterns of insects and birds that used this part of the Adelaide plains. Using this theory the Bushtops do not need to be connected but could be a series of isolated building roofs forming stepping-stone habitats. This also can be taken another step further by introducing living walls into the system to connect with the ground plane creating stepping-stone corridors vertically as well as horizontally. In the Adelaide CBD this also could be connected to the surrounding parklands and landscaped squares, so that all are linked via stepping-stone corridors.

The following projects that I visited on my fellowship have outstanding examples of elements or design principles that support the development of the Bushtop green roof system.

**Green Roofs**

- Terry McGlade – residential roofs, mini plant associations that are planted for certain aspects and conditions together on the same roof

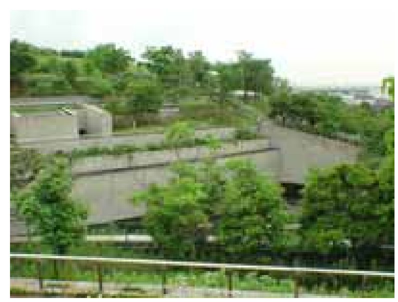
- Irish Hunger Memorial – a wild grassland plant ecosystem

- Tokyo Roppongi- this incorporates a working rice paddy that demonstrates natural and cultural ecosystems

- Osaka Gymnasium – municipal park/cultural type ecosystem

*Irish Hunger Memorial New York*

*Rice paddy on 6th floor Roppongi Hills, Tokyo*



*Osaka Municipal Central Gymnasium*

**Living Walls**

- Canada Life Board room has a Biowall (bio-filtration) living wall and fish pond that are integrated together and support each other

- Japan's living wall systems on building façades (up to 4 stories high)

- Singapore's Botanic Garden living wall connecting two levels via the wall

**Elevated Landscape -** best opportunity for bushtops because of the depth of substrate and topography, and producing a new ground level. The potential disadvantage is that there is a continual connection to the existing ground allowing predator movement, if that was an issue.

- HighLine – this is elevated and has a break with the existing ground level but the current design does not take advantage of the potential eco system design

- Millennium Park – migratory birds use this for nesting

- Naoshima – green roof is mimicking and replacing the existing ground level

*Millennium Park, Chicago*

*Chichu Art Museum viewed from Benesse House, Naoshima, Japan*

**Ground to Rooftop Corridor**
This is a combination of eco-roof and living walls where animals, insects and birds can move freely from the ground to the roof. It demonstrates the biophysical principle of bushtops and the following examples could be used as a guide to future projects.

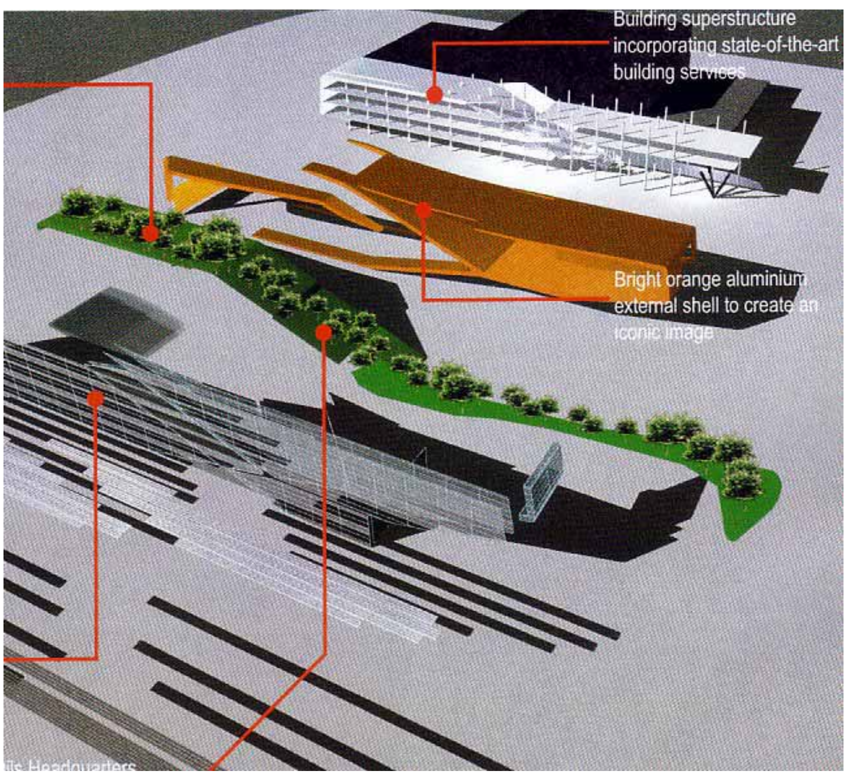
- ACROS Building, Fukuoka - each storey stepped to the roof

*Acros Building, Fukuoka*

- Island City Park, Gringrin, Fukuoka - continuous flow from the ground over the building in a uniform layer

*Island City Park, Fukuoka*

- Mewah Oils Headquarters, Malaysia - continuous vegetated ramp from ground to sky garden




*Design detail for Mewah Oils Headquarters by TR Hamzah &Yeang showing vegetated ramp*

# Elements that are Components of Bushtops

There are a number of elements that are the driving forces and rationale for using green roofs and living walls. Each community will need at least one, and possibly more, of these elements or drivers to propel the green roof movement. In North America the drivers are heat island effect and stormwater management (as they have both stormwater and sewage in one system and the increasing stormwater load is making the system untenable). In Japan the drivers are heat island effect and air pollution, whereas in Basel, Switzerland, the sole driver is biodiversity.

Possible drivers are:

- Stormwater management
- Air pollution reduction
- Reduction of heat island effect
- Reduction of building energy usage
- Increased open space and biodiversity

**Stormwater Management** can reduce volumes and temperatures in runoff, thus allowing existing stormwater infrastructure to remain in place and reducing capital expenditure on increased volume infrastructure. Also by reducing the volume less downstream erosion occurs. With the lower stormwater temperatures there is an increase in water quality and habitat improvements.

*Water retention after 7hrs rain event on ACROS building, Fukuoka*

**Air Pollution Reduction** by plant removing airborne particulars and chemicals through bio-filtration and looking up heavy metals in the root systems. They improve the carbon dioxide effect through the carbon dioxide/oxygen exchange in photosynthesis.

*Bio-filter system in Toronto*

**Heat Island effect can be reduced** by lowering the surface temperature of the building surface and thus the surrounding ambient temperature, as well as reducing the reflective temperatures to the local environment. This lowers the amount of energy used for cooling, thus reducing the consumption of fossil fuels.

*Chicago City Hall rooftop*

**Reductions in building energy use** through thermal insulation results in general reductions of 10% for multi storey buildings and 20% for single storey buildings. This reduces the heating and cooling requirements for the building and thus the energy costs.

**Increased open space and biodiversity** is obtained through utilization of the roof and vertical walls for vegetation. Rooftops particularly provide increased open space in medium and high density cities for active and passive recreation.

**Construction and new technologies**
Green roof technologies have developed quickly in other parts of the world, especially the development of extensive roof systems. These systems have been researched and developed in response to growing demand. They are cheap and light weight (50mm thick and weighing as little as 75kg per $m^2$), and some systems can be retro-fitted over metal deck roofs, such as the system developed by Richard Tan of Envirospace from Singapore.

*Singapore trial of extensive system retro-fitted over metal deck*

Living walls are being developed at speed, especially in Japan where they are being developed by building and creative innovator companies to produce off the shelf systems. These living wall systems are flexible and show a variety of uses, and would be extremely useful in Australian conditions.

In Canada I saw examples of the Biowall system, a new technology that integrates a living biological system into the building air handling system to remove airborne pollutants and deliver cleaner air to the building occupants. This system is most effective when placed in front of air conditioners' intake grills.

*Biowall system that draws air through vegetation before entering air conditioners, JAS Robertson building, Toronto*

Photo voltaic cells can be made to produce more efficiently by locating them on a green roof instead of the normal roof surface. It has been shown in studies that green roofs have lower surface temperature than non green roofs and that these photo voltaic cells work less efficiently at the extreme high temperatures that are common on traditional roof surfaces.

*Photo voltaic cells on Centre for Green Technology rooftop in Chicago*

**Policies**

To implement green roofs it is wise to have a green roof /living wall policy at a national or state level to encourage and co-ordinate this movement. The two cities that are leading this movement through government policy are Chicago and Toronto. Both cities have lead by example by placing a green roof on their City Hall.

*Chicago City Hall rooftop*

*Toronto City Hall rooftop*

These cities are currently implementing policies that require a percentage of green roof for new buildings and providing some cash incentives or grants as well as streamlined approval processes. These policies have been developed over the last couple of years through experience and observing other cities with similar issues.

The common agreement is that a demonstration green roof needs to be developed and tested for local conditions so that reliable research can be used to demonstrate the advantages and reduction of energy use within the local environment. Without this research it is hard to promote the benefits of green roofs and living walls to the community and to building professionals and developers.

There are many ways to develop green roof policy through trial and error processes or by a process that I experienced through the Green Roofs for Healthy Cities organisation. This organisation developed an effective green roof policy program that required a community development process. This process consisted of the following key phases:

- Introductory/championing
- Green roof symposium/education
- Action plan development and implementation
- Technical research
- Program and policy development
- Assessment and continuous improvement

Both Chicago and Toronto are in the last two phases of the above process. I believe it is important for Australian cities to develop and carry out this process to achieve a sustainable green roof and living wall movement.

# Conclusion

Australia's green roof and living wall industry is in its infancy and almost no research or information gathering has occurred, resulting in no platform of knowledge, except for the very few working in the area who are protecting their commercial knowledge.

There have been very few, if any, trials using Australian plants in either green roofs or living walls. This is an area of considerable research potential as there are many native plants that appear to be suitable for this application. Given Australian varied climatic conditions much research and information is needed to provide sufficient information for design and construction professionals to design systems and install vegetation that will be sustainable.

The few green roofs and living walls that are already installed around the country should be monitored with weather stations and instruments, providing valuable research information so that a body of information can be gathered for a variety of climates throughout the nation.

The main drivers for Australian east coast cities would be heat island effect, together with stormwater reduction and increasing open space. Drivers for smaller cities such as Adelaide would be biodiversity through stepping-stone corridors and connecting to the existing open space system. In Adelaide this could be developed as a new elevated parkland above the CBD, formed by green roofs and living walls connecting the city squares to the existing surrounding parkland.

This fellowship has allowed me to visit many amazing and interesting projects around the world, but there is one project that stands out as being closest to my research topic, and that is the Roppongi Hills Keyakizaka sixth floor rooftop garden in Tokyo. This integrated green roof combines natural and cultural living systems.  It features a functioning rice paddy that produces 60kg per year and is planted by the local school children as an important educational activity.  It also boasts an organic vegetable plot, as well as a living ecosystem featuring a breeding colony of frogs in the water feature/creek/pond, and a barbeque area for corporate functions.

*Frogs enjoying their habitat on the 6th floor at Roppongi Hills, Tokyo*

This Tokyo rooftop demonstrates that a living ecosystem and a cultural rural ecosystem can work together with human recreational intervention. In addition, its outstanding feature is the multi layers of function and their integration with the building design. The rooftop is isolated from the rest of the building by scissor-shaped hydraulic shock absorbers. This is an innovative earthquake design which allows the rooftop mass to counterbalance the rest of the building movement.

I am indebted to the Winston Churchill Memorial Trust for enabling me to experience such a range of projects at first hand and to meet people working in this field.

# Recommendations

My recommendations fall into two types: firstly, what I can do as a result of the fellowship experience; and secondly, what should occur now in Australia.

**What I can do**

- Promote the environmental benefits for bushtops and living walls for the urban built environment and also for the inside building environment
- Target interest groups such as Architects, Landscape Architects, Planners, Urban Designers and Building Owners through public talks, lectures and articles
- Initiate research and on site information gathering for the thermal insulation performance of bushtops and living walls so that energy consumption figures can be developed for Adelaide and used for future projects
- Initiate State and Local government policy processes for bushtops and living walls as part of Adelaide's sustainable development agenda and planning policy

**What should occur now in Australia**

There needs to be much broader research for rooftops and living walls. This research should be developed by both private and government sectors:

- Trialling Australian plant species suitability
- Investigating suitable ecosystems for bushtops
- Investigating rare and endangered fauna and flora for bushtops

Similarly, research into the new technology of living walls should look at issues like:

- Shading effect and temperature on building walls
- Bio-filtration effect for air intake for air conditioners
- Reduction of air pollutants and what species to use

Also research should be directed to look at the potential of food production of roof tops and vertical walls, especially in the urban contexts.

Government policy should be developed to encourage bushtops and living walls as part of the Green Building requirements and provide an incentive program for these elements.