Considering the Application of Biophilic Urbanism

A Sustainable Built Environment National Research Centre (SBEnrc) Briefing Report – November 2011
Project 1.5: Considering the Application of Biophilic Urbanism

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Synopsis

Biophilic urbanism, or urban design which reflects human's innate need for nature in and around and on top of our buildings, stands to make significant contributions to a range of national, state and local government policies related to climate change mitigation and adaptation. Potential benefits include reducing the heat island effect, reducing energy consumption for thermal control, enhancing urban biodiversity, improving well being and productivity, improving water cycle management, and assisting in the response to growing needs for densification and revitalisation of cities. This discussion paper will give an overview of the concept of biophilia and consider enablers and disablers to its application to urban planning and design. The paper will present findings from stakeholder engagement related to a consideration of the economics of the use of biophilic elements (direct and indirect). The paper outlines eight strategic areas being considered in the project, including how a *'daily minimum dose'* of nature can be received through biophilic elements, and how planning and policy can underpin effective biophilic urbanism.

Acknowledgement

This paper has been developed with funding and support provided by Australia's Sustainable Built Environment National Research Centre (SBEnrc) and its partners. Core members of SBEnrc include Queensland Government, Government of Western Australia, John Holland, Parsons Brinckerhoff, Queensland University of Technology, Swinburne University of Technology, and Curtin University. This project has been supported by the following partners, acknowledging the key persons contributing to the project: Western Australian Department of Finance (Carolyn Marshall and Anna Evers), Parsons Brinckerhoff (Shaun Nugent and Darren Bilsborough), Townsville City Council CitySolar Program (Greg Bruce, Mark Robinson and Chris Manning), PlantUp (Jonathon Grealy) and Green Roofs Australasia (Matt Dillon). The research team is based at the Curtin University Sustainability Policy Institute (CUSP) and the QUT Faculty of Built Environment and Engineering (FBEE). Graphic design and copy editing has been undertaken by the Parsons Brinckerhoff publishing team as part of its in-kind commitment to the project.

Citation: Reeve, A, Hargroves, K, Desha, C, Bucknum, M & Newman, P 2011, 'Considering the application of biophilic urbanism: a Sustainable Built Environment National Research Centre discussion paper', Curtin University and Queensland University of Technology.

1. Introduction

EO Wilson first popularised the concept of biophilia in the early 1980s with his landmark book of the same name[1], later clarifying the concept in *The biophilia hypothesis*[2], saying: 'Biophilia … is the innately emotional affiliation of human beings to other living organisms'. In considering how to apply this to urban planning, leaders such as Tim Beatley and Peter Newman have contributed to the creation of the field of 'biophilic urbanism'.[3] It reflects a growing need to landscape not only the spaces between buildings but the buildings themselves. Nearly every new urban development across the world is seeking to incorporate green qualities into its structure and function, and many are seeking to display biophilic elements, such as green roofs, green walls and plant installations.

When the Sustainable Built Environment National Research Centre (SBEnrc) was established to highlight areas of innovation in our cities, it was quickly realised that this would form an important part of the future of cities in Australia and around the world. This discussion paper presents the findings of literature research and the results of workshops with stakeholders facilitated by the research team from Curtin University and QUT. The project is mentored by the father of biophilic urbanism, Professor Tim Beatley, who inspired the team through a set of memorable presentations while on his Fulbright Scholarship at Curtin University. The discussion paper presents eight strategic areas for research.

2. Why is the application of 'biophilia' important to urban planning?

Australia has one of the highest urbanised populations in the world, with around 90% already living in cities and large towns. This is predicted to remain the situation for the foreseeable future, with only 6% of the population living outside urban areas in 2050.[4] By mid-century it is also anticipated that the global urban population will have doubled, with over two-thirds of the world's population living in cities and megacities.[5] This concentration of people in urban environments is putting increasing strain on systems, such as energy and water supply, civil infrastructure provision, manufacturing, and food production and distribution. Furthermore, these systems are being strained as they attempt to reduce their greenhouse gas emissions while also creating innovative products and services to compensate for increasing costs of energy and diminishing access to many resources such as fresh water. The predicted impacts of climate change on Australian cities and the systems that support city dwellers are significant and are likely to have major implications. The convergence of such urgent and challenging issues provides strong impetus for developing systems-based solutions that can reduce the speed and severity of these issues.

A growing body of global evidence demonstrates how 'biophilic elements', or natural, green infrastructure (such as green roofs, vegetated walls, constructed wetlands, street trees, community gardens, planted swales, tree canopies over streets, etc.) can make a range of direct and indirect contributions to economic development. Early efforts to apply biophilia to urban planning have focused on landscaping on and around buildings, and have prompted investigations on the wider application across cities. Further integrating such elements into urban design may help adaption to many of the impacts and consequences of climate change, such as increased urban temperatures (exacerbating the urban heat island effect), increased energy demand, intensified storm events, loss of biodiversity and declining agricultural yields.

As mentioned, the concept of biophilia was first popularised by EO Wilson over 25 years ago[6], has since been explored within the social and psychological disciplines, and is now receiving much attention to consider its application to urban planning and design. Wilson suggests this innate affiliation to other living organisms may come as a result of human evolution, in that this has created a pre-conditioning to be more likely to respond with a particular behaviour when presented with a particular stimulus. For example, Wilson postulates that such pre-conditioning (referred to by Wilson as 'gene-culture co-evolution') may manifest as an aversion to and fear of snakes. Poisonous snakes can cause death and illness, and almost universally elicit a strong natural fear and fascination. Across a wide variety of cultures, snakes are the most commonly dreamed about animal, and feature prominently in cultural beliefs and mythology. In the case of monkey and ape communities, the aversion has resulted in a specific signal to warn of the presence of snakes that can cause the entire primate group to react and leave the immediate area. Wilson suggests that humans quickly develop a fear of snakes

with very little negative reinforcement (also to dogs, spiders, closed spaces, running water, and heights) but are less quick to develop a fear of more modern threats, such as guns, knives, cars or electric wiring, which are equally dangerous if not more so. Wilson proposes that the constant exposure to snakes over evolutionary time, and the likely natural selection of those members of a population who recognised the danger of snakes, made an appropriate behavioural response, and survived, has genetically predisposed their offspring to a similar hereditary aversion and fascination.

Herein is the key to biophilia. Wilson suggests the current population of the human race has a genetic predisposition to (an innate dependence on) desiring a relationship with nature that is beyond material and physical needs because those with such a disposition have prevailed in our evolution.

Studies have shown that a connection to nature can lead to reductions in depression, anger, tension and fatigue. Having been applied to a number of aspects of psychology and interior design, the concept is now receiving strong interest as an urban design principle, not only for the wellbeing benefits to humans, but for a range of direct and indirect economic and environmental benefits, especially in such utilitarian issues as cooling cities as climate change–induced heat island effects increase. With our connection to nature steadily reducing in cities around Australia, a more biophilic city is likely to reduce the sense of population pressures as our cities grow and, more particularly, as they become denser, to reduce car dependence.[7]

Biophilic urbanism conceptually extends beyond the physical conditions, or the use of green design and natural elements in a city, to include how connected and engaged those who live there are with nature and their surrounds. Hence Beatley advises that in addition to considering the size and number of biophilic elements within a city, it is important to consider how well they are used by residents, and whether they create opportunities for people to enjoy, care for and appreciate nature.[8] Biophilic design can be applied at multiple scales, including at the level of a building, street, city and region, and the greatest benefits are likely to be derived from the simultaneous consideration of all these scales. Furthermore, when biophilic design and green infrastructure plans are coupled the resulting urban form promotes energy security through decentralised embedded generation (and less reliance on fossil fuels), water security through greater ability to capture runoff (and less reliance on groundwater, which in many cities is being severely damaged by saline intrusion) and food security through introducing more urban agriculture.

Image courtesy of Plant Up

3. How can biophilic urbanism be applied to Australian cities?

Biophilic design is an urban design principle that identifies how cities can be planned for and retrofitted to incorporate a greater degree of the natural environment (e.g. green roofs, living walls, daylighting urban streams). Timothy Beatley suggests that there is no strict definition of a biophilic city, but many different expressions of urban biophilia, which manifest as different combinations of biophilic elements, qualities and conditions. To provide an overarching definition, Beatley suggests that: *A biophilic city is a city that seeks to foster a closeness to nature — it protects and nurtures what it has … actively restores and repairs the nature that exists, while finding new and creative ways to insert and inject nature into the streets, buildings and urban living environments.*[9] Using a process based on the methodology of 'Collective Social Learning'[10], created by Emeritus Professor Valerie Brown, participants of a project stakeholder workshop held in Perth in September 2011 brainstormed potential elements that might be part of the application of biophilic urbanism (see the results in Table 1).

Table 1: Possible applications of biophilic urbanism

• Green (vegetated) roofs • Green (vegetated) walls (incorporating vines and trellises) • Daylighting streams (referring to uncovering waterways contained in pipes, under roads or under urban landscapes) • Creating wildlife corridors along infrastructure corridors based on tracked migration patterns (such as roadways) • Community information centres providing knowledge on local species and environment • Creating storm/sea buffer zones with vegetation • Vegetable gardens, and community gardens • Greening verging strips, including with food production • Street trees and canopies over streets, including for food production • Internal plants and vegetation for buildings (incorporating aquaponics)	• Parks (connected by wildlife corridors) • Urban constructed wetlands (incorporating stormwater and wastewater capture and treatment) • Shopping centre greening (as communal public spaces, and taking advantage of increased sales in greened commercial districts) • Running water (incorporating water capture and storage, and evaporative cooling) • Shade plantings (strategic planting to reduce internal building temperatures in summer) • Swales (rather than traditional stormwater conduits) • The use of natural light and ventilation in buildings • Green sidewalks (rather than pavement) • Connectivity within green spaces and greenways

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Source: SBEnrc Stakeholder Workshop, hosted by the Western Australian Department of Treasury and Finance (held at the Optima Building) and facilitated by Curtin University and QUT,
13 July 2011, Perth.

Table 2: Summary of key enablers and disablers to the application of biophilic urbanism

Enablers	Disablers
• Innovative and adaptive frameworks • Leadership by planning authorities • Social pressures – community forums • Local and state government policy able to be informed by BU metrics • Demonstration sites e.g. New Delhi (UHI), Ulrich (health benefits) • Community gardens and associated community groups • Corporate donations and sponsorship • Supportive local governments that are connected to the needs of community • Availability of vacant lands to be used as biophilic elements • Growing level of education, experience and exposure to nature in cities • A lot of good work being driven at grassroots level	• Planning frameworks (business as usual) • Lack of quantitative/financial analysis of BU (rather than qualitative) • Cultural stagnation • Control issues (e.g. at local government level there are internal struggles about control and how things happen) • Lack of Information at the level of the decision makers (e.g. buildings, town planning) • Lack of research on local, holistic systems • Benefits/costs fragmented • Regulations/planning permit requirements • Lack of integrated planning • Lack of rigorous cost–benefit analysis using a systems approach • Level of social disconnection to natural environments

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and QUT, 13 July 2011, Perth. SBEnrc Stakeholder Workshop, hosted by Parsons Brinckerhoff and facilitated by Curtin University and QUT, 7 September 2011 Brisbane.

When then asked to consider what might be enabling or disabling the application of the elements in Australian cities, the participants brainstormed a number of institutional, information and market factors, as summarised in Table 2.

A key finding of the stakeholder workshop, which was clearly evident in the literature review done as part of preparing the project, was that although there was a growing number of studies attempting to quantify the performance of particular biophilic elements (such as green roofs), there is a clear need for further quantification of the costs and benefits, a valuable contribution to underpin the increased coverage of biophilic urbanism in various government policies and planning schemes. Examples of economic benefits identified in the literature review include:

- Street trees can provide aesthetic and functional benefits to road users, pedestrians and neighbourhoods. Research into the use of street trees suggests that these provide wide financial and social benefits, with one study on the Davis community in California, USA, estimating the 24,000 public street trees provided about US$1.2 million net annual environmental and property value benefits, with a benefit to cost ratio of 3.8:1.[11]
- Experiments on the use of shade trees at residential houses in California found that installing eight large and eight small shade trees could reduce cooling energy use by 30%, or around 4 kWh per day, with peak energy savings of 0.7 kW. In Florida, a similar experiment using a mobile trailer revealed

reductions in airconditioning electricity consumption of 50%.[12] Sustainability Victoria noted that using plants to shade a building can reduce the internal temperatures of a house in summer by between 6 and 12°Celsius.[13]

- Chicago's Millennium Park remains one of the most famed examples of the transformation of a paved parking and railyard area into potentially the world's largest green roof, creating a 24.5-acre (close to 10 ha) park incorporating performance venues, art, sculpture, architecture and landscape architecture. Beneath the park, the railyard continues to operate alongside a 2,218-space parking garage and a large bicycle garage with facilities for repairs and showers. Around half of the park area is permeable 'green roof', with the remainder incorporating pathways, buildings, fountains, artworks and other attractions. The Millennium Park has become a place for musical events, tourism, cultural expression and recreation. The US$490 million project has increased nearby property values by a total of US$1.4 billion, and increased tourism revenues by US$2.6 billion.[14]

- The use of well-placed green walls has been found to greatly reduce indoor temperatures in buildings – for example, a study in Tokyo revealed a 10ºC difference between exposed wall surfaces with and without plant screening, while in Beijing a 28% reduction in the peak-cooling load transfer to a building's interior was observed when a green wall was installed on the west façade. These findings are supported by studies in Canada, which reported a 23% reduction in energy consumption for summertime cooling.[15]

- Vertical and rooftop gardens can be used for food cultivation, making use of space throughout an urban area and facilitating the production of food close to where it will be needed.[16] For example, the Fairmont Royal York hotel cultivates herbs, fruits and vegetables on the hotel's rooftop garden to supply the restaurant. The 18-storey-high, 372 m^2 garden provides a wide variety of fresh produce, including many ingredients not widely available through supermarkets or distributers, and has recently introduced bees. Having pioneered the concept, the Fairmont Royal York has been an inspiration for many other restaurants throughout Canada, Singapore, Hawaii, Dallas, San Francisco and Washington, DC, with benefits including cost savings, energy savings, fresher produce and better flavours.[17]

- Research indicates that indoor plants can improve the environment by removing pollutants, such as volatile organic compounds, nitrogen and sulfur oxides, particulate matter and ozone, and reduce indoor carbon dioxide levels. Reduced illness has been associated with indoor plants, including reduced sick leave in office staff and school children, reduced respiratory illnesses, lower blood pressure, reduced attention fatigue and increased worker satisfaction. Similarly, indoor plants have been found to increase worker productivity, improve creativity, increase attentiveness and improve ability to perform tasks. Staff working in environments with one or more plants show reduced levels of anxiety (37% less), anger (44% less), depression (58% less), fatigue (38% less), confusion (30% less), overall negativity (65% less) and overall stress (50% less).[18]

- A study of Los Angeles, California, investigated the underused potential of alleys throughout the city, finding that although most are walkable and quiet, they are generally dirty and unsafe.[19] It is estimated that there are over

1,450 km of alleys in Los Angeles, presenting a valuable resource in a relatively land-poor city.[20] If such alleyways were able to be greened, it would be possible to create recreational opportunities in park-poor neighbourhoods; encourage walking and cycling through increased connectivity and added amenity; improve water quality and supply through reduced impervious surface cover and use of stormwater management devices, such as bioswales and pervious pavements, reduce urban temperatures, enhance biodiversity, and reduce crime through improved lighting and increased use of alleyways. Similar assessment of the value of Melbourne alleyways has led to their revitalisation, including some biophilic elements.

To identify key considerations for an economic argument for biophilic urbanism in Australia, participants of the stakeholder workshop were asked to consider what they felt were the factors that would be most important to decision makers. These findings (see Table 3) will be combined with additional stakeholder engagement workshops and interviews to inform the development of an economic analysis tool for considering the application of biophilic urbanism in Australian cities.

Table 3: Potential economic indicators and metrics, and considerations for economic analysis of the application of biophilic urbanism

Potential economic indicators and metrics	Key economic considerations
• Staff retention rates • Infrastructure costs vs. payroll costs • Temperature and HVAC cost differences • Building inputs and outputs – connection with biophilic elements • Health costs and savings, especially those related to particular biophilic elements and experiences (for example, being outdoors for a certain amount of time, a view of nature through the window) • Some measure of economic viability – being an attractive place to live/work etc. • Returns on investment	• Other measures of progress to accompany an economic argument (such as human happiness/experience) • The audience for an economic argument (there may be several) • The different between innate benefits and tangible benefits • 'Dynamic localism' and economic benefits • Non-linear multiplicative benefits • Costs and benefits longitudinally, 'now' workers and 'later' intergenerational: this may allow long-term impacts and benefits to be included in the economic argument

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It is the purpose of the Biophilic Urbanism project to explore the key issue of quantifying and interpreting the performance of biophilic elements in Australian urban environments and provide strategic guidance to industry and governments tasked with creating and maintaining our growing cities.

4. How is biophilic urbanism being used in cities?

Case study: The High Line Park, New York City

The High Line Park was developed on a disused elevated freight line on the lower west side of Manhattan, New York, and now extends for 1.5 miles and covers 6.7 acres. The park retains much of the original architecture and feel of the rail line, with wild flowers and grasses growing between the cracks of concrete pavers and in purposely designed gardens. The park has developed significant green space within New York, increasing nearby property values and creating a marketable 'brand' for nearby businesses. The urban revival sparked by the High Line has created interest for a similar conversion of disused infrastructure in other cities into green space.[21]

Case study: Portland, Oregon

The City of Portland, Oregon, has been converting traditional streets into green streets over several years, using water-sensitive urban design elements, such as bio-infiltration pits and rain gardens built into stormwater curb extensions and sidewalks, to capture and infiltrate runoff from the road and pavement. These gardens provide visual amenity and habitat, clean the runoff, reduce sewer backups in basements, reduce street flooding and combined sewer overflows (CSOs) to the Willamette River, enhance pedestrian and cyclist safety, and reduce the urban heat island effect.[22] The green streets are valued so highly by residents and visitors to Portland that maps are provided for a 'green streets tour' of some of the best examples throughout the city.[23]

Case study: Vauban, Freiburg, Germany

Vauban is a suburban district in the Germany city of Freiburg, which has adopted an 'ecological traffic and mobility concept' in which car driving is discouraged through a number of regulations. With low car usage and the consequent reduced need for infrastructure (roads, parking space), Vauban has extensive, connected green space throughout the medium-density district. Residents played an active role in directing and designing the development of the green space, which includes intensive local food gardens, parks, old-growth pockets and public green spaces.[24] The development does not involve green roofs but has extensive green walls covered by vines and other plants grown on frameworks. There were several initiatives that reduced car usage in Vauban. For example, households may own a car, but must park it in one of two multi-storey car parks on the perimeter of the district at a substantial cost rather than at their house. Consequently, over 40% of households do not have a car, and none have more than one. Cycling and walking are the favoured means of transport, accounting for 64% of all trips. A car-free life is facilitated by a car-sharing association, which also provides free annual public transit for the entire Southern Black Forest region and a free BahnCard, which provides a half-price subscription pass for German rail. It is aided by deliberate policies to encourage shops and businesses to establish throughout the district, although movement of these businesses into the ground floor of mixed-use buildings has been slow.[25]

Case study: Australian Government: Biodiversity Conservation Strategy

Australia's Biodiversity Conservation Strategy 2010–2030 provides a guiding framework for the next 20 years. Among the national targets are the aims to increase the number of Australians and public and private organisations that participate in biodiversity conservation activities by 25%

by 2015, to double the value of complementary markets for ecosystem services by 2015, to significantly increase native and restored habitat reserved for biodiversity conservation, and to improve ecological connectivity.[26] This strategy operates at a continental scale; however, it has implications for Australian cities, particularly in increasing the degree of engagement of Australians with biodiversity conservation and in restoring and preserving habitat and connectivity. As over 80% of Australians live in cities, Australian cities may provide ideal opportunities for habitat that the majority of Australians can engage with on a daily basis, rather than biodiversity conservation being viewed as something that occurs outside cities. Examples of how this is already occurring in cities, especially in Australia, have been set out.[27]

Case study: Chicago Green Alley program

In Chicago, the Department of Transportation initiated the Green Alley program to better manage stormwater, using green infrastructure rather than traditional stormwater drains. Although the Chicago Green Alley program does not specifically aim to increase biodiversity in the city, this case study lends weight to the possibility of retrofitting alleys throughout a large, highly developed city. Comprising 1,900 miles (3,000 km) and 3,500 acres (1,400 ha) of alley space, most without any sewer or drainage infrastructure, alleyways are a significant and extensive piece of infrastructure in Chicago. Alleyways were retrofitted with permeable pavements, high albedo pavements, proper pitching to ensure excess stormwater drained to the street sewers, and energy-efficient lights that shine downwards towards the alley rather than up towards the sky. Since the initial pilot program in which six alleys were retrofitted, more than 80 of Chicago's alleys have been retrofitted.[28]

Case study: Seattle Street Edge Alternative

Seattle completed a pilot Street Edge Alternatives project (SEA Streets) in 2001, in which residential streets were redesigned to reflect natural drainage patterns through the use of bioswales, evergreen trees and shrubs. These redesigned streets had on average 11% less impervious surface than conventional streets, and reduced the stormwater runoff by 99%. Summer heat was reduced on targeted streets, and there were anecdotal reports that residents were happy with the project. A second, expanded project was completed in 2006, which encompassed 16 blocks and used the same tools as the pilot. In addition to managing stormwater flows and preventing flooding, the SEA Streets project aimed to recharge groundwater, reduce pollutant transport, provide healthy wildlife habitat in creeks, and improve neighbourhoods. The program met the technical aims but there were problems with verbal agreements with residents over the maintenance of the vegetation; some residents kept these agreements while others did not. Later efforts to engage residents were met with limited success, and in 2008 the city began to investigate alternative maintenance arrangements.[29] Similar examples of water-sensitive urban design are given in Beatley and Newman.[30]

Case study: Village Homes community, Davis California

Village Homes is a well-established 70-acre housing development in Davis, California, which began in 1975 and today includes 225 houses and 20 apartments. Most houses use passive solar design, and all showcase sustainable design integrated with nature. There are 23 acres of greenbelts, orchards, vineyards, vegetable gardens and edible landscape, and swales run throughout the village to capture and direct rainwater to irrigate the trees and orchards. Households share the communally grown produce, adhering to an honour system through which they only take the food that they can consume.[31] The community has the same density as neighbouring suburbs, and maximises the amount of green space available, in part through reducing the width of the streets and not having additional pavements beside the roads. The roads are curved with many cul-de-sacs, and just less than 8m wide, reducing the speed of traffic and making it more convenient for most residents to cycle and ride. There are extensive walking and cycling paths linking common areas and passing through landscaped and garden areas, enhancing the travel experience. There are also two large parks, extensive greenbelts, two vineyards and two large common gardening areas. The area does not include biophilic elements on top of roofs or on walls.[32]

Case study: Berlin, Germany

In Berlin, Germany, new building developments are required to leave a certain proportion of the development area as green space, with the proportion referred to as the Biotope Area Factor (BAF or BFF for Biotop Flächenfaktor). The BAF is otherwise defined as the ecologically effective surface area per total land area. Because of the high density of Berlin, there was strong concern over the degree of soil sealing, inadequate replenishment of groundwater, low urban humidity, increased urban temperatures and biodiversity pressures. One key advantage of the BAF system is that it allows the developer to decide how to incorporate the green space, providing flexibility while still achieving the goal of greater city green space. Various green space and surface coverings are given a weighting to estimate their contribution to the green space goals. The BAF builds on earlier green space planning initiatives, such as the Courtyard Green Program, which subsidised the development of green roofs, green facades and backyard community gardens, which resulted in 86.5ha of green space and facades.[33]

Case Study: Seoul, Korea

In Seoul, Korea, a 10-lane freeway that had been built over a major river was removed and replaced with an urban park 6km long, running alongside the restored Cheong Gye Cheon River. Fish, birds and insects have repopulated the area, which is about 3.6ºC cooler than other parts of the city. The area is widely used by city residents and visitors, and incorporates art, historical plaques, walkways, markets and landscaping. The project was initiated by the local community because of widespread concerns over the health impacts from the large volumes of traffic using the freeway, and the decreasing stability of the structures. There was some opposition to removing the freeway, mainly due to concerns that it would result in traffic congestion, and that businesses would suffer economic losses during construction. To alleviate congestion, a transportation policy was introduced with a primary focus on public transport; the city also provided a stability fund to help businesses suffering any adverse impacts during the construction period. Around 4,000 meetings were held with over 20,000 residents, both individually and in groups, to encourage participation and address concerns. The restoration took 27 months, with construction costs of around $281 million. Almost all (96%) of the asphalt and concrete from the dismantled freeway was recycled, as was all of the reinforcing steel. Although the river is far from natural, incorporating concrete- and granite-lined channels and embankments, water treatment plants, walkways and clay mats, it nonetheless provides the city with many of the benefits of a natural stream and considerable increases in biodiversity have been measured.[34]

Case study: Malmö, Sweden

In the Western Harbour project of Malmö, Sweden, new developments are required to have an average green space factor of 0.5, with each surface covering scoring a green rating between 0 and 1. For example, an impervious surface rates as 0.0 while a tree is 0.4 and a green roof 0.8. The first phase of the project, Bo01, has 1,000 homes, and maximises green space by reducing road infrastructure while maintaining relatively low-density housing. Developments must achieve a minimum of 10 'green points', which are awarded for the inclusion of elements that encourage biodiversity, such as bird nesting boxes, butterfly flower beds, a wide diversity of wildflower species and deep soil. Visible waterways feature in the landscape, and are fringed by trees and undergrowth to provide aesthetic, stormwater and biodiversity benefits. The Bo01 development is intended to showcase how urban development can increase environmental quality.[35]

In another example, the inner-city, high-density suburb of Augustenborg in Malmö is a well-cited case study of retrofitting an existing suburb with an open stormwater system incorporating green roofs, swales, open channels, ponds and a small wetland. Augustenborg is unusual, as there are few examples of such a retrofit; most open stormwater systems have been introduced during the design phase of new developments. The original use of combined sewers in Augustenborg was resulting in overflows from the sewers and flooding in basements and garages during heavy rain, prompting a rethink of the stormwater management system in 1997 as part of a broader urban renewal project. Implementing a conventional, separated sewer would have necessitated major earthworks and may have encountered problems related to joining newer stormwater drainage networks to an older system not designed for such flows. The retrofit adopted a three-pronged approach: reducing the runoff response from (or efficiency of) the impervious area; conserving open space and aesthetics; and reducing the total flow of stormwater. The design of the stormwater system was complicated by existing land uses (e.g. buildings, car parks, parks) and the values and concerns of residents (i.e. preserving aesthetics, function and sanitation). These have imposed design limitations, and consequently the arrangement of the various elements in the system is somewhat ad hoc. Further, concerns over potential property damage from deep percolation of rainwater have meant that geotextiles have been used underneath many of the elements in the system. Analysis of the system reveals the importance of all elements, which act to varying degrees to reduce the total flow volume (through storage capacity in substrate, ponds, wetlands etc.) and to attenuate flow peaks (through low-frequency, high-intensity storage capacity in ponds). The retrofit was completed in 2001, and besides some initial teething problems, it is now effective to such an extent that the combined sewers are receiving wastewater almost exclusively (i.e. almost no stormwater is entering the combined sewers). Many of the drainage elements in the system function also as recreational areas; for example, a shallow infiltration strip in a schoolyard doubles as a miniature amphitheatre, and the use of design features surrounding channels and ponds create aesthetically pleasing features in the urban environment.[36]

5. What are the key strategic areas for investigation?

Strategic Area 1: Transforming roads and paved areas (including permeable pavements, high albedo pavements, bioretention areas, urban trees and forest (street trees), conversion of disused road infrastructure to parkland, green streets, and promoting alternative transport to reduce road infrastructure)

In most cities, one of the greatest constraints to urban renewal and urban greening is the lack of available space and existing infrastructure. The proportion of space in cities typically dedicated to road infrastructure is significant. For example, in Europe, road infrastructure consumes on average 25% of urban areas and in the USA 30%. In Los Angeles, road infrastructure accounts for 40% of the city area.[37] However, cities that have focused on promoting alternative forms of transport, commonly termed 'walking cities', on average devote only 10% of the land space to streets and parking.[38] Hence, there is hence a significant potential to recapture land within cities through reducing dependence on private automobiles and converting road infrastructure to alternative land forms. At the same time, roads can increase their use of street trees so that canopy coverage can reduce heat absorption in asphalt and concrete.

Strategic Area 2: Incorporating green space into the built environment (including biodiversity corridors in urban environments, green streets and alleys, land development to enhance biodiversity refuges and corridors, green roofs, green walls, city farms and urban agriculture, and constructed wetlands)

Incorporating green space into urban areas can play a vital role in providing habitat and refuge for flora and fauna, while also improving the climatic and hydrologic conditions to mitigate the impact of the urban areas on surrounding ecosystems. Preserving existing biodiversity and green space in new urban developments can ensure mature trees and other vegetation are available to fauna already living in the area, and may help create a sense of place and connection for residents. For example, most of the old trees in Vauban, Germany, were preserved during its development and are now considered to be the 'jewels' of the suburb, with extensive and carefully planned green space and green corridors designed along side them.[39]

Strategic Area 3: Climate control in buildings and the built environment (including shade trees, vegetated areas to reduce reflection (lawns, gardens), green walls, green roofs and indoor vegetation)

A key consideration for the development and retrofit of urban areas is to ensure buildings are liveable and functional in a future with increased temperatures, greater density and potentially limited energy resources. Many urban buildings are viable only through mechanical heating and cooling, which requires vast amounts of energy and contributes to the urban heat island effect. Such buildings are also required to be completely enclosed so the interior can be kept significantly cooler than the outdoor ambient temperature. This results in symptoms commonly collectively termed 'sick building syndrome', including tiredness, headaches, mucosal membrane symptoms, and skin irritation and disorders caused by the build-up of air pollutants. Specific building disorders are also identified in some cases, as well as enhanced transmission of infectious diseases.[40] These considerations provide considerable impetus for addressing building design and operation. As Janis Birkland[41] outlines, existing buildings and cities need to be retrofitted, as it will not be possible to substantially improve the sustainability of the built environment through the construction and use of new buildings alone.

Strategic Area 4: Mitigating the urban heat island effect (including urban parks, street trees, green roofs and green walls)

The urban heat island effect is a well-researched phenomenon affecting most cities around the world, and is expected to be exacerbated by climate change. The effect is mainly due to the increased amount of heat generated from urban structures, which consume and reradiate solar radiation, and from anthropogenic heat sources (such as cars, airconditioners and industry).[42] The impact of these heat sources is exacerbated by the urban form, which tends to have minimal vegetation (thereby minimising the cooling benefits of evapotranspiration and shading of paved areas), high surface roughness and decreased sky view factor (which reduces convective heat removal). In Australia, as much as a 75% increase in heat-related premature mortality is predicted in some Australian cities by 2050. Human health can be compromised by exposure to heat stress for as little as 48 hours, with deaths related to heatwaves exceeding those from all other climatic events.[43] The effect has other implications, including increased energy demand to create a comfortable living environment, and increased ground level ozone (ozone is produced at a higher rate at higher temperatures). Although in some cities, the increased urban temperatures can create independent breezes as the warm air rises, drawing in cooler air from the surrounding areas, in others the urban form produces stagnant conditions, which can result in a highly polluted urban atmosphere, causing cardiac and cardiopulmonary disease and death.[44]

Strategic Area 5: Enhancing carbon emission reductions and sequestration (including soil organic carbon, carbon sequestration by urban shade trees, reduced greenhouse gas emissions due to shade trees, mangroves, green roofs and green walls)

Urban soils and vegetation play a dual role in climate change mitigation by storing carbon, as well as reducing the production and emission of carbon dioxide through reducing energy demand. Fossil fuels account for around 93% of Australia's electricity generation, with renewable energy sources constituting only 7%, the majority of which is hydro-electricity.[45] As electricity generation contributes a little over 35% of Australia's total greenhouse gas emissions,[46] reducing energy demand can greatly enhance carbon emission reductions. There may be systemic, cascading greenhouse gas reductions from increasing urban biophilic elements. For example, there is evidence to suggest that by increasing shade vegetation and places with natural amenity, residents are more likely to walk and cycle, further reducing greenhouse gas emissions from automobiles. Reducing reliance on automobiles will result in reduced road and car park space, both typically covered with dark asphalt. Replacing such areas with lighter coloured pavement or vegetation will increase the surface albedo, reducing the urban heat island effect and energy consumption.

Strategic Area 6: Enhancing urban water cycle management (including green roofs, green walls, constructed wetlands, ponds and lakes, daylighting and restoring streams, vegetated swales, infiltration basins and swales, and infiltration trenches and soak ways, sidewalk and roadside gardens)

The effects of urbanisation on the hydrological cycle can be seen in intensified stormwater runoff, diminished groundwater recharge, reduced baseflow and enhanced stream channel and river erosion. These effects are largely the result of increased impervious cover on roofs, roads and pavements. This prevents rainwater from penetrating the surface, increases the speed and volume of runoff during rainfall, and decreases runoff during periods of low rainfall. These urban changes also affect the quality of stormwater runoff, which is frequently contaminated with pollutants collected from roads, gardens and roofs and without the natural filtering processes provided by vegetation and soils.[47] Green infrastructure provides multiple opportunities to enhance water cycle management through returning to, or replicating, many of the features and functions of the original landscape in a watershed.

Strategic Area 7: The economics of biophilic urbanism (including financial and non-financial costs and benefits, along with benefits to society and the wider urban system)

Each of the above strategic areas has economic implications that can be estimated and drawn into the basis of a framework for consideration by planners and developers. As part of the feasibility of a biophilic urbanism a series of economic questions can be asked to inform further efforts, such as: was an economic case presented to demonstrate the viability of the intended installation that considered both financial and non-financial elements; what were the actual direct and in-direct costs of the installation compared to the estimates; what were the construction and maintenance costs; was financial support received for the project; what was the return on investment period; were economic multiplier effects identified; and have studies on occupant or pedestrian experience been done. When considering the benefits to society, the research team will use the 'daily minimum dose' of nature methodology being developed by the project's mentor Professor Tim Beatley.

Strategic Area 8: Underpinning effective biophilic urbanism (including planning and policy considerations, and identifying opportunities for biophilic urbanism related inclusions)

As with economic considerations, each of the strategic areas has planning and policy implications that can be explored to create a framework to support governments in underpinning effective biophilic urbanism in Australia. As part of the feasibility of a biophilic urbanism a series of planning and policy questions can be asked to inform further efforts, such as: what were the biggest challenges in developing this biophilic urbanism element, and how were these overcome with government support; what were the greatest opportunities that catalysed the development of this biophilic urbanism element, and how were these capitalised on; what policy tools were used in causing the development of this biophilic urbanism element; how effective were these policy tools.

6. What is the focus of the biophilic urbanism project?

Given the strong collaboration between university, industry and government on the SBEnrc, the project's initial focus has been on preparing for and using a range of stakeholder engagement activities to inform its outcomes. The project has a dual focus on both the economic and policy considerations of biophilic urbanism and has developed a set of strategic questions for each to allow case study evaluation. The project will be developed through a number of steps:

- Literature review. A comprehensive literature review by the research team produced a summary of findings of over 22,500 words that was then refined to produce a 57-page summary. The literature review provides a valuable overview of a number of strategic areas, and was used as the basis of the stakeholder engagement
- Stakeholder engagement. A series of stakeholder meetings have been held along with the facilitation of three stakeholder workshops involving over 30 participants, in Perth and Brisbane. The workshops were based on the methodology of 'collective social learning', created by Emeritus Professor Valerie Brown,[48] to guide participants through a process to consider first their vision for a biophilic (nature-loving) city and the aspects that enable and disable achieving such vision. Then the various elements of an economic consideration of both direct and indirect economic benefits and costs of the use of biophilic elements in cities and urban areas were used in a brainstorming activity
- Case study assessment. The team is focusing on assessing case studies to consider the economic and policy considerations to inform the use of biophilic elements
- Report and recommendations. Each of the three key areas will produce a report that will focus on outlining the associated findings. This will include a report on the key elements and aspects of biophilic urbanism, especially those related to building landscaping; a report on the economic considerations of the use of biophilic elements; and a report on the policy considerations to underpin the wider uptake of biophilic elements. Each of the outcomes will be focused on providing value to partners and will continue to be developed in close collaboration with stakeholders.

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Sustainable Built Environment National Research Centre

The Sustainable Built Environment National Research Centre (SBEnrc) is the successor to Australia's CRC for Construction Innovation. Established on 1 January 2010, the SBEnrc is a key research broker between industry, government and research organisations for the built environment industry.

The SBEnrc is continuing to build an enduring value-adding national research and development centre in sustainable infrastructure and building, with significant support from public and private partners around Australia and internationally.

Benefits from SBEnrc activities are realised through national, industry and firm-level competitive advantages; market premiums through engagement in the collaborative research and development process; and early adoption of SBEnrc outputs. The SBEnrc integrates research across the environmental, social and economic sustainability areas in programs titled Greening the Built Environment; Developing Innovation and Safety Cultures; and Driving Productivity through Procurement.

Among the SBEnrc's objectives is collaboration across organisational, state and national boundaries to develop a strong and enduring network of built environment research stakeholders and to build value-adding collaborative industry research teams.

SBEnrc core partners:

Government of Western Australia
Queensland Government
Parsons Brinckerhoff
John Holland
Curtin University
QUT
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