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ENVIRONMENT DESIGN GUIDE

DESIGN FOR ECO-SERVICES

PART A – ENVIRONMENTAL SERVICES
PART B – BUILDING SERVICES

Janis Birkeland

Summary of

Actions Towards Sustainable Outcomes

Environmental Issues/Principal Impacts

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

Basic Strategies

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

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

Cutting EDGe Strategies

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

Synergies and References

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

ENVIRONMENT DESIGN GUIDE

DESIGN FOR ECO-SERVICES
PART A – ENVIRONMENTAL SERVICES

Janis Birkeland

Without the virtually free services of nature like clean air and water, humans would not last long. Natural systems can be incorporated in existing urban structures or spaces to add public amenity, mitigate the heat island effect, reduce pollution, add oxygen, and ensure water, electricity and food security in urban areas. There are many eco-solutions that could radically reduce resource consumption and pollution and even provide surplus ecosystem services in the built environment at little or no operational cost, if adequately supported by design.

This paper is the first of a two part paper that explains what eco-services are, then provides examples of how design can generate natural as well as social capital. Using examples of actual and notional solutions, both papers set out to challenge designers to 'think again', and invent ways of creating net positive environmental gains through built environment design.

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

Figure 1: Using solar energy for low cost water purification
(Source: MAGE Water Management, Germany, 2004)

1.0 INTRODUCTION

1.1 Is there a Problem?

Thirteen million deaths are blamed on nature each year (Prüss-Üstün and Corvalán, 2006). Nearly all of these deaths, from floods, fires, mudslides, pollution, typhoons and malaria are exacerbated by poor planning and design. Not only have we built on earthquake faults, near coastlines subject to sea rise, storm surges and tsunamis, in fire prone areas such as dry Eucalypt forests and so on, we have made people in cities dependent upon water pipes, electricity wires, roads and fossil fuels – any one of which can be cut off in a war, civil emergency, or extreme weather event.

The list of negative environmental impacts embedded in our conventional systems of development (including construction, agriculture and transport), is almost endless. The economic cost of environmental damage can be greater than the value of resources and services they provide (Li, 2008). Moreover, for the most part, these industrial systems lock us into a fossil fuel supply chain, encourage more consumption, and limit more sustainable options in the future.

The built environment can give back to nature more than it takes if we introduce multifunctional natural systems that provide for natural security, goods and services, and replace mechanical (fossil fuel based)

Positive Development:
That which creates net positive ecological and social impacts in addition to repairing the environmental damage caused by previous development and restoring ecosystems to their previous state. It aims to expand both the:

- ***ecological base*** (i.e. ecosystem goods and services, natural capital, biodiversity and habitats, ecological health and resilience, and bio-security (resistance to pandemics, etc).
- ***public estate*** (i.e. equitable access to and expansion of the means of survival for all).

POSITIVE DEVELOPMENT
Examples of additional eco-positive services that could be provided by eco-positive design

- Provide habitat for elements of the food chain (e.g. pollinators)
- Grow healthy materials and fibres to offset impacts of materials extraction and use
- Increase oxygen in urban areas with extra plants (i.e. not just sequester carbon)
- Turn sewage and organic waste into fertile soil (e.g. integrated vertical composting)
- Increase production of goods and services in excess of the needs of the project itself (e.g. growing food, pharmaceuticals)
- Treat off-site pollution production in excess of the waste of the project itself (e.g. sewer mining)
- Support natural systems that eliminate pests and diseases (e.g. fish in ponds eat mosquito larvae)
- Draw water from air in humid climates
- Provide specialised habitat for indigenous species beyond what was originally on site
- Store water to conserve the environment during droughts
- Seek opportunities to prevent flood, fire and storm damage at the building and urban scale
- Replace fossil fuel powered systems (e.g. air conditioning) with passive systems where possible
- Actively mitigate the urban heat island effect (e.g. green roofs)

Current aspirations of sustainable design

REGENERATIVE DEVELOPMENT
Eco-services sometimes provided by autonomous and/or regenerative design

- Recycle organic wastes
- Sequester carbon
- Control pests and diseases (e.g. by avoiding stagnant water, non-chemical termite control)
- Treat pollution produced by project (e.g. clean air and greywater)
- Utilise solar energy to heat, cool and/or ventilate
- Store water for irrigate landscaping
- Avoid toxic materials and chemicals
- Avoid building on flood plains and landslide areas
- Slow storm water runoff
- Reduce soil erosion and sediment loss

Box 1: Eco-services – distinguishing regenerative from eco-positive design

building services. Natural systems can be integrated with urban and building services without taking space from human uses. This presents an economic opportunity as well as a design challenge, as the eco-retrofitting of cities (that is, physical development) is necessary to correct the ongoing problems and risks caused by past design norms. It is now well established that eco-retrofitting can pay for itself in savings of energy and water (Romm, 1999). But as we will see, there are many other material and physiological benefits that can be gained. We can begin the conversion from negative to net positive impacts immediately through the eco-retrofitting of cities using *design for eco-services* (Birkeland, 2003b).

1.2 Eco-services

Ecosystem goods and services ('eco-services') are natural systems that provide essential life support services for humans such as heating, cooling, food, waste treatment, water purification, etc. (see Box 1). Although we already use some of nature's 'free' services in the built environment (such as winter sun for warming or summer breezes for cooling), we seldom capitalise on other ecosystem services to create positive ecological and social gains.

We are gradually learning to use the (virtually) free services of nature, such as algae, moving water, gravity, wind power, air circulation and convection, and bacteria to provide clean power, air, water and food, and to perform building services (e.g. heating, cooling and ventilating). While most building services rely on fossil fuel powered equipment, natural services operate without toxic fuels. Both mechanical and eco-services need maintenance, but natural systems could potentially become self-managing, self-organising, and self-perpetuating if they were given the same research and development that has gone into 'modern' buildings.

1.3 Beyond Regenerative to net Positive Development

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

Box 1 distinguishes eco-positive from regenerative design. Although these are on a continuum, most ecological designers have only aimed for regeneration, reflecting the (tacit) dominant paradigm that holds that 'development' of the built environment can at best, only repair the damage that has been done. As well as correcting and over-compensating for the ongoing damage of past development decisions, Positive Development would increase the ecological base relative to pre-settlement conditions (see the author's EDG paper GEN 6: *Ecological Waste: Rethinking the Nature of Waste*).

Using pre-settlement ecological conditions as a measure provides an objective 'Sustainability Standard' against which development can be assessed (see the author's EDG paper GEN 4: *Positive Development: Designing for Net Positive Impacts*). In contrast, the current practice of most rating tools for buildings only measures the degree to which a building is less bad than a typical building of the same kind.

Measuring net positive impacts requires new support tools, and the author is working in partnership with others to develop a new 'positive' form of life cycle assessment (Birkeland and Jones, 2010).

1.4 Examples of Eco-service Technologies

These two papers offer a few of many examples of design concepts and eco-technologies that create or support ecosystem services, which have been collected by the author and her students. In some cases, there are high-tech products that are perhaps not net positive, but which can be bought off the self and applied to new or old buildings, while others are low-tech design concepts that could, if cleverly applied and combined, have net positive impacts over their life cycle. Such eco-solutions can be modified to increase their applications and positive benefits.

This is *not* a shopping list. It is intended to inspire imagination by looking at different scales of the built environment, from products to landscapes. It hints at the wider range of design concepts that could be combined in new or existing buildings or scaled up to an urban or regional level. These examples will hopefully help readers to invent their own eco-solutions, leading to a new eco-positive form of architecture.

2.0 PURIFICATION OF ESSENTIAL RESOURCES

2.1 Toxin removal

There are thousands of man-made chemicals in the environment whose affect on humans or the environment has not been tested (NPI, 2007). We do not know how these chemicals will react with each other in the air, water and soil, nor do we know much about how they bio-accumulate in human tissues and react with immune systems over time. Because measuring negative impacts is difficult, it would make more sense to use natural materials and processes that are known to be safe, rather than industrial materials whose impacts may not be fully understood. Measuring positive impacts is relatively easy. For example, the quality of the air and water entering and exiting a building could be compared to ensure they are improved.

Natural systems act collectively to decontaminate the air, water and soil, and increase useful microorganisms as required for the job. For example, plants eat carbon and produce oxygen, microbes and earth worms convert contaminated land into fertile soil, vegetable bio-solvents have been used to clean up oil spills, and reed beds treat water pollution. Many of these processes can be considered net positive as they not only repair the environment, but can provide food, resources and profits.

Figure 2: Hair and used to clean up oil spills

Mats made of salvaged human hair are used to soak up toxic oil spills. In a trial in San Francisco, California, green waste and worms were added to the oil soaked hair mats to remediate the waste.

(Source: MatterOfTrust.org, Photograph: Lisa Craig Gautier, 2007)

Mushrooms: Mushrooms can transform some toxins chemically, such as crude oil, so that the mushrooms are still safe to eat. Insecticides that are non-toxic to humans are being developed by mushroom expert Paul Stamets, of British Columbia, to replace both harmful agricultural and domestic poisons. Quick growing mushrooms have been used to temporarily stabilise forest roads to reduce erosion and create a base for forest regeneration (Stamets, 2005). They have also been used to restore ecologically damaged habitats, filter water, and breakdown toxic wastes.

Cork: Volatile Organic Compounds (VOCs) can damage the liver, kidney, and central nervous system and are suspected carcinogens (EPA, 2009). One can add a VOC-removing material, such as cork containing micro-organisms found in natural soils

along with plant nutrients, spores and seeds, to remove air pollution (Guieysse, *et al* 2008). The cork wall can become part of a living wall of moss, ferns, creepers and epiphytes, that seals off existing harmful materials. Such living walls and green scaffolding can also encase or ameliorate harmful chemical by-products on existing interior or exterior walls (Duffy, 2004).

2.2 Water

Unsafe drinking water leads to about 6 million deaths around the world each year. Access to water is increasingly being privatised, and in some parts of the world, subsistence farmers can no longer obtain water from their traditional sources (Caldwell, 2003). In Australia, the past compartmentalisation of water, sewerage and stormwater agencies has contributed to the failure to understand whole system flows (Wong, 2008). Water may become the main limiting factor on new development in Australia, as rain can be irregular, and it is impractical and energy intensive to transport water long distances. In response to the high energy costs of pumping water, the US State of California reduced 25 percent of the energy consumption of its water system by making it more efficient (Gabriel, 2009). Centralised water grids can lose 12-30 per cent water and 1-9 per cent energy in transmission, and once built, this infrastructure has limited ability to adapt to change (Hess, 2008).

In sub-tropical cities such as Brisbane, summer humidity is a major cause of discomfort, even in times of severe water restrictions. Yet it is inexpensive to collect water from humid air and purify it via passive solar systems that use evaporation, as this only requires plants, glass or plastic and sunlight. Water can also be treated in vertical landscapes such as chains of planters, or green roofs which add visual amenity to the urban environment as well (Osmond, 2002).

Inexpensive water distillation: Lightweight, economically-produced plastic cones can be used as solar-powered water purifiers as shown in Figure 1. They extract freshwater from dirty or salinated water through evaporation, as clean water rises and runs down the surface of the glass or plastic. This simple technology, already being used in the developing world, could be integrated with building elements such as skylights, or green scaffolding (Birkeland, 2007a).

Permeable pavers: Water runoff from urban environments produces problems with quick flowing, high volume runoff, which can result in costly urban flooding, require high infrastructure costs to control, and reduce subterranean aquifers. Aside from high nutrient loads (and thus pollution), water systems can be degraded by high temperature run off, as biota in the water are not adapted to over-heated and contaminated water runoff. Some pavers are designed to absorb water and improve water quality by filtering pollutants, thus saving city governments significant costs in infrastructure for stormwater runoff (Velazquez, 2008).

2.3 Sludge and sewage treatment

Over a third of the people on the planet do not have toilets or adequate sewage treatment, which results one of the major causes of death and disease in the world (www.worldwatch.org). Modern water based sanitation is capital and resource intensive, so the resource flows that would be entailed in giving everyone this form of sanitation would have huge environmental impacts. However, there are a growing number of examples around the world where natural systems have been used instead of capital and resource intensive sewage systems. For example, a village in China used restorers combined with boardwalks to retrofit canals that had previously been used as open sewers which cleaned the water to an excellent standard (Oceanarks, 2009).

A number of microorganism-powered sewage treatment concepts have been developed by scientist John Todd of OceanArks (Todd, 1994) and others such the systems designed by the Australian inventors Dean Cameron and Peter Jones. Some have been used successfully to improve the water quality in ponds and streams, and to treat sewage and sludge from factories, buildings and neighbourhoods. In some cases, industrial and agricultural waste inputs have been combined to produce compost for food production. Likewise, abattoir waste has been converted to fertilizers and compost products for sale to farms.

Figure 3: Vetiver on raft used as floating water purifier, Toogoolawah, Queensland

(Source: Dr Paul Truong, 2005)

The Living Machine: Living machines are a train of ecosystems supporting microbes that treat organic waste. The first tank may contain algae and microorganisms which decompose the organic waste, and aquatic plants which take up the remaining nutrients (Todd, 2002). The next tank may be an artificial marsh of sand, gravel, and reeds to filter out remaining organic waste and algae. The following tank may contain snails and zooplankton that consume the remaining microorganisms. Fish eat the snails and can then be harvested for bait. The Australian Conservation Foundation's retrofitted '60L' building in Carlton, Melbourne, displays a living machine in its lobby that processes the building's greywater (ACF, 2008).

River restoration: On the same principle as living machines, restorers are floating ecologies on rafts that can clean lakes, reservoirs or ponds. Similarly, Vetiver and other selected plants can be grown at the water's edge or used in floating trays, as seen in Figure 3. Vetiver is a non-invasive, clumping grass with an extensive root system that treats contaminated water and tolerates high levels of heavy metals and agricultural chemicals (Vetiver, 2009).

2.4 Climate change mitigation

Even if there were no such thing as global warming, the urgency to reduce fossil fuel usage would be just as pressing for a wide range of other reasons. Not only will fossil fuels eventually run out, they are harmful to people at every stage of the supply chain (Scheer, 2002). Greenhouse Gas (GHG) emissions could be dramatically reduced by retrofitting the built environment. Buildings are said by some to be responsible for around 30 per cent of GHG emissions (although estimates vary), and emissions from buildings could be reduced cost effectively with existing technologies by more than a third (Brown et al., 2005).

The whole system benefits of forests have been neglected in the recent emphasis on GHG emissions and industrial sequestration systems. Deforestation is nominally held responsible for only 20 to 25 per cent of climate change, but forests are a core part of a complex, self-adjusting feedback mechanism that regulates climate and carbon (CSIRO, 2007). As the whole system benefits of forests becomes better understood, the value of reforestation will be more evident (Adger and Brown, 1994). Introducing forests in urban areas have proven to have positive social as well as environmental impacts (Shakur, 2008).

Urban trees and green roofs: Particulates are a significant cause of lung disease. Tree-lined streets have a fraction of the dust and particulates found on similar streets without trees (Oberndorfer, et al, 2007). Street trees, green roofs and living walls can reduce the urban heat island effect, which shortens life spans of thousands of city inhabitants each year (IFRC, 2004). Green roofs cause urban air to circulate as well as helping to clean the air, and it has been found that green roofs in a climate such as Brisbane's can cool solar panels, increasing their electrical generating capacity by 10 to 15 percent (Chua, 2009).

Figure 4: A vision for London with algae grown in building elements

(Taken from the report Geo-Engineering: Giving us Time to Act? courtesy of Institution of Mechanical Engineers, 2009)

Algaetecture: 'Algaetecture' refers to growing algae in tubes combination with building elements. When exposed to sunlight, algae produces oxygen and bio-fuels very efficiently while simultaneously sequestering carbon. Carbon dioxide from industrial processes can be bubbled up through plastic tubes, which, as these tubes take up little area, could be combined with screens or double skin exterior walls The UK's Institute of Mechanical Engineers has proposed wrapping buildings in photobioreactors of algae (2009) as shown in Figure 4. Design students working with the author at QUT suggested such technology could potentially be used to convert car fumes from road tunnel exhaust towers into biofuels and oxygen. Other proposed that service stations could produce their own bio-fuels from algae farms in multi-story greenhouses above their buildings.

Carbon dioxide absorbent concrete: Concrete production is increasing and accounts for an estimated 5 percent of global carbon dioxide emissions in Europe and America, and 10 percent in China (Dyer, 2003). Olivine is a green-coloured mineral which is reputedly capable of absorbing, over its life, ten times more carbon dioxide from the air than is emitted during concrete production (Cement and Concrete Centre, 2008). Sand and gravel can be replaced by olivine in exposed, porous concrete. Similarly, cement which integrates reactive magnesia (in the form of magnesium oxide) sequesters carbon, and entails lower embodied energy and carbon dioxide in production than standard limestone based Portland Cement (Tececo, 2009).

Figure 5: Green scaffolding can be used to add eco-services to the exterior of existing buildings

(Source: Birkeland, 2007a)

2.5 Air cleaning

Poor indoor air quality has been ranked as the fourth most critical world health problem (WHO, 2009). While poor indoor air quality in developing nations is often caused by smoke from cooking, a third of modern buildings are believed to generate complaints of 'sick building syndrome'. Off-gassing of harmful volatile organic compounds, formaldehyde, electro-magnetic fields, and bacteria in air conditioning systems (legionnares' disease) and so on, can turn urban living into a toxic miasma (Creighton, 2002). Asbestos is still found in homes in Australia (at least of those built before 1984) and toxic fibres may be released into the environment during renovations or demolition.

We have largely excluded plants from the built environment, except for decorative purposes. Yet research has shown that living near a green space has measurable health benefits, especially the reduction of depression (Loh, 2008, Kellert, 2005, Mansor, 2008). Stress levels in people living and commuting in urban areas without greenery have been shown to be higher than those living and working in greener environments.

Interior living walls: Placing an indoor plant every 10m2 can reduce indoor air pollution by 87 per cent according to NASA (Wolverton, 2008). An average house would need around 17 plants in large containers in order to see a notable difference in air quality. However, if one has little floor area, planters can easily be supported by the wall or ceiling. A three story high living wall, located in the main lobby of a building at Queens University in Canada was designed to act as a natural air filter to remove VOCs and carbon dioxide as air passes through the wall into the office spaces via the mechanical system (Queens University, 2009). There are now irrigation systems for living walls that regulate water automatically by using capillary action, making maintenance easy (Dyer, 2009).

Green Scaffolding: Green scaffolding is a concept for a modular system that could wrap around the facades of existing buildings, thus providing multiple ecosystem services and environmental amenity, and potentially

Figure 6: Man made 'air trees' proposed to create the Eco-Boulevard, Madrid, Spain

(Source: Urban Ecosystems)

increasing the building's longevity by reinforcing the structure and protecting the facades from weathering (Birkeland, 2007a). A variety of 'ecopods' supported by triangular truss structures could passively heat, cool, ventilate the interior, treat waste and produce food, and even support small endangered ecosystems. The engineering firm ARUP (Brisbane office) and the author are currently refining how such a system might work as a new building in a proposed sustainability education centre project (www.sustainability.org.au).

Urban Ecosystems in Spain have similarly proposed an 'air tree' for Madrid (Figure 6) as a way to improve urban climatic conditions, creating a social meeting place as well as enriching the public domain. The round, free-standing green scaffolding system supports plants and solar panels that are designed to feed back into the electrical grid (Urban Ecosystems, 2007).

3.0 AGRICULTURE

3.1 Soils

Desertification and soil degradation are increasing around the world, while agricultural productivity is going down (Kumar, 2008, Irshad, 2008). Australia's soils are relatively poor and face increasing salinity which impacts upon biodiversity as well as food productivity. Compost can improve soil structure for both agriculture and native plants, and can be produced and delivered to the farm gate cheaper than to landfill (Gillespie, 2008). In the Groundswell project being trialled in NSW as an exemplar of systems design, a cooperative system for organic waste collection, treatment, and value adding to agricultural land (Groundswellproject, 2009).

Bio-char: To reduce the atmospheric concentration of carbon and climate change, carbon can be sequestered in soils using bio-char (Lehmann 2007). Bio-char is charcoal created by biomass burned in a low oxygen fire. According to the CSIRO, producing bio-char and using it to sequester carbon reduces carbon in the atmosphere, as well as increasing crop yields in some cases (CSIRO, 2009). When added to soil it improves soil fertility and water quality through filtration, and sequesters carbon (Anzbiochar, 2009). Adding bio-char to agricultural land has costs, but it can provide a measurable basis for allocating carbon credits to farms through emission trading schemes, and thus help to revitalise the farming sector.

Vertical composters: There are only a few vertical composting units in Australia, but they are proven to work as a no-odour method of composting waste that can be integrated with the urban environment. One composter at the University of New South Wales uses bacteria that work at high temperatures and are able to eat particularly smelly gases. Urban composters would reduce land fill and transport, while producing fertilizer which could be used for urban applications such as parks and vertical agriculture (Figure 7).

Vermiculture: Worm farms are another form of composting that turn waste into fertile soil, though existing worm farms are usually operated independent of buildings. However, there are now building-integrated systems that can provide pre-composting material for the vermiculture industry. The Joe Serna Jr. California EPA Headquarters Building diverts waste from landfill, saving US $500,000 in waste management costs. Such systems can handle over tonnes of organic waste per day (refer to www.usgbc.org).

Figure 7: Vertical composting unit at Royal Botanic Gardens, Sydney

The small footprint of these units, and their ability to contain odours makes it possible for them to be incorporated into buildings, close to the waste source.

(Source: Photo: Botanic Gardens Trust, 2002)

3.2 Food production

As agricultural land becomes more degraded and depleted, and transport costs increase, it is likely that growing food in cities will become relatively more economical. Community gardens are growing in popularity as a source of uncontaminated organic produce. With over 50 per cent of the world's population living in cities, damaging industrial farming practices, and a projected three billion increase in the human population by 2050, vertical farming may become a necessity, regardless of cost. As land values rise, arable land becomes scarcer, and as natural systems become recognised as essential, vertical farming could eventually be seen as a necessity.

A wide variety of produce can be harvested in quantities large enough to sustain urban populations without

Figure 8: Eco-productive self-contained home integrated system

(Source: Phillips, Biosphere Farming Concept)

relying on significant resources from beyond the city limits. One proposal, by Dr. Dickson Despommier of Columbia University, would house a million square metres of hydroponically-grown produce which could feed 10 thousand people per day (Verticalfarm, 2009). Abandoned multi-level warehouses could be retrofitted for indoor farming and vertical composting businesses, which could collect organic waste from nearby residents and restaurants.

Aquaponics: Aquaponics is a vertical food production system that forms a 'closed loop', where fish faeces provide the nutrients for hydroponic plant production. These systems can already be purchased off the shelf for urban balconies or back yards. One manufacturer claims that such a system which uses gravel, not soil would require uses 90 per cent to 95 per cent less water than in-ground farming, and minimal energy and labor for the same output. It reputedly can grow over 27,000 kg vegetables and 9,000 kg of fish per year, and only requires one person to operate (Figure 8) (Portablefarms, 2009).

Home integrated systems: Aquaponic type systems can be combined with indoor furniture or window bays. Closed loop systems have been designed which produce vegetables, fish and cooking gas, while filtering water and absorbing carbon dioxide. They can even incorporate a methane digester that produces heat and gas to power lights, while algae produce hydrogen and root plants produce oxygen (which is fed back to fish).

Vertical hydroponic systems: The use of space in double skin high-rise facades for hydroponic vegetable production has been proposed. Crops are cultivated in modules containing rows of trays suspended on adjustable cables that rotate up and down the facade for optimal light and shade, and allow harvesting at ground level. Preliminary modelling for a New York City site indicates that each 80 m2 module will yield 3000 kg of fresh produce, conserve 300 tons of fresh water, avoid up to 4 tons of carbon dioxide emissions, and replace 0.1 hectare of cropland (Puri, 2008).

3.3 Biodiversity protection

Urban consolidation (increasing population in existing urban areas) is currently thought to reduce the impact of cities, but it is often done in a way that increases total resource consumption (Birkeland and Schooneveldt, 2002). It can mean more environmental impacts, simply concentrated in a geographically confined area. Depending on design, the resource flows in high density living can be greater than in low density (Do, 2008). While the land area occupied by cities is relatively small (about 2 per cent of the Earth's surface), cities often occupy the most ecological and economic valuable land, such as fertile land by rivers. Cities and infrastructure not only reduce arable land area but also divide and destroy ecosystems. Over the last two decades a movement has evolved to reverse this effect by exhuming water systems that have been covered by concrete, to create urban amenity and create wildlife corridors that restore original eco-systems.

Due to the pressures on ecosystems and biodiversity caused by both agriculture and urban development, vertical farming could eventually become necessary even in rural areas. The land slowly released by vertical food production would free up more space for eco-services and habitats for biodiversity. Farmers may someday be able to sell ecosystem services to industries needing to offset carbon emissions, thus funding the gradual increase of food production and restoration of wilderness.

Nature corridors: Train corridors can be eyesores and reduce property values due to crime, noise and visual pollution. However, some existing railways and tram lines are being converted to green corridors or planted median strips. New and retrofitted tram developments in several European cities now have lawns instead of gravel, with examples in Barcelona, Frankfurt, St-Etienne and Strasbourg. In lieu of using grass that requires mowing and toxic fertilizers, low-maintenance native ground covers would support more urban biodiversity and create nature corridors.

Bio-tunnels: Bridges and tunnels have been retrofitted to freeways in the countryside to provide safe crossings for animals whose habitats and migration cycles have been divided. They can also serve social functions. For example, Mercer Island residents in the US city of Seattle requested that a lid be put on the freeway which allowed sport fields, tennis courts, picnic areas, and jogging paths to be added to what previously was a dead concrete megastructure. Similarly some have proposed that railways or freeways be enveloped in modular and continuous green envelopes. Some existing modular green wall products have proven to be effective acoustic baffles.

Green alleys: There is a growing movement to 'green' alleyways in some countries. In Melbourne CBD, there has been an effort to reclaim public alleys from 20,000 industrial rubbish bins belonging to private businesses (Harrison 2009). Bio-swales, rain-gardens and nature corridors have been integrated with alleys and other dead spaces to increase public and environmental amenity. Green alleys can reduce runoff and urban flooding, while supporting vegetation and social activity. As QUT students proposed, windowless alley walls could be leased to businesses such as 'rock climbing' facilities, which could be integrated with vertical landscapes for oxygen production and water filtration.

4.0 CONCLUSION

In summary, there are a range of eco-solutions available for all dimensions, levels and scales of the built environment, from products to bioregions. Some reduce pollution and waste, but others appear to go beyond 'closed loop' systems to be eco-productive as well as profitable, such as Living Machines and algae farms. They can be designed to suit divergent design preferences and unique urban contexts and microclimates.

The second part of this paper gives examples for building and urban environments.

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BIOGRAPHY

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