**August 2007 • Gen 4 • Summary** (Edited 05.09.2018)
*This note was reviewed as up to date and leading edge for time of publication by Author in September 2018 with update not applicable.*



# Positive Development: Designing for Net Positive Impacts

**Janis Birkeland**

***Summary of***

## Actions Towards Sustainable Outcomes

### Environmental Issues/Principal Impacts

- Conventional 'green buildings' only reduce the amount of damage we otherwise would have done; they still substitute natural systems and ecological productive functions with unsustainable industrial processes.
- If all buildings were impact neutral, cities would still not be sustainable. Sustainability requires the eco-retrofitting of existing development to provide the infrastructure and space for eco-services.
- Buildings and cities could be designed to increase the ecological base and improve human and ecosystem health without sacrificing space for human functions, amenity and life quality.

### 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:*

- Our building performance assessment tools currently focus on predicting and measuring future negative impacts. This is impossible in a complex system, and has caused us to forget to 'design in' positives.
- Good design would leave the air, water, soil, biota and people in a healthier condition than before, while Positive Development would go beyond remediation to add social and ecological value.
- A 'sustainability standard' would be where an environment is more resilient, its biodiversity healthier, and its people better off after construction than before.
- To assess positive ecological impacts relative to the status quo, we can use ecological space – the effective ecological area provided in development – as a surrogate for eco-services.
- Increase ecological space, that provides eco-services including:
  - 'Green scaffolding' – a second skin on an existing building that supports the urban ecology, increases the building's lifespan, provides heating and cooling, supports the ecology, etc.
  - 'Green space frame walls' – new building structures that integrate functions (e.g. heating, cooling air and water cleaning, power generation) with eco-services, social and biological functions, etc.

### Cutting EDGe Strategies

Some of the ways we can encourage net Positive Development are:

- award points for the inclusion of ecological space in development guidelines, building rating tools, development approval processes, etc
- award bonus development rights such as additional floor area, to developments that improve off and onsite ecological conditions
- establish mortgage systems that provide incentives for eco-retrofitting or other developments that provide ecological space
- create trading mechanisms such as transferable development rights for ecological space.

### Synergies and References

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- *BEDP Environment Design Guide:* PRO 22: How to Approach Material Selection for Waste Minimisation

BEDP ENVIRONMENT DESIGN GUIDE

# Positive Development: Designing for Net Positive Impacts

Janis Birkeland

*This paper challenges the prevalent 'green building' design approach that treats nature as a resource rather than a living eco-system(s), and aims only to minimise the net negative impacts on the environment. It argues that buildings and cities could increase the ecological base as well as improve the economic and social health of surrounding regions. Genuine Sustainability would require the eco-retrofitting of existing development to provide the infrastructure and space to improve ecosystem health and increase natural capital. The good news is that this can be done without sacrificing space for human functions, amenity and life quality. However, it would require a very different kind of environmental management, planning and design.*[1]

**Keywords**

*eco-services, eco-innovation, ecological base, ecological space, eco-retrofitting, Positive Development, public estate, sustainability standard, design for eco-services, green scaffolding*

## 1.0 Introduction

Poor urban design and architecture kills more people each year than terrorism. In just two weeks for example, 26,000 deaths in Europe resulted from the 'urban heat island effect' (which means cities are several degrees hotter than their surrounds). In Paris more people died in one day from heat related causes than died in the 9-11 attack on New York's World Trade Centre. The design of cities both creates and conceals negative cumulative impacts such as toxic chemical exposure, air pollution, fossil fuel dependency, inequitable distribution of wealth and life quality, vulnerability to extreme weather events, insecurity of access to the means of survival (e.g. food, energy and water), and a diminishing range of future social options (Barlow and Clarke, 2003). The world's population already exceeds global carrying capacity (UNEP, 2005); therefore urban development must increase the globe's net carrying capacity.

The good news is that most negative environmental impacts are caused by physical and institutional design, and can be reversed by re-design. Cities could increase the earth's natural life support system and improve human and environmental health. Arguably, wilderness areas can only be 'restored' once degraded: their carrying capacity cannot be increased without disrupting ecological relationships. So if we do not turn our urban areas into ecologically productive systems, we cannot achieve global sustainability, let alone save our remnant wilderness areas.

## 2.0 What is the ecological base and just how can cities provide eco-services?

The term **ecological base** is used in this paper to mean the whole natural life support system, including:

- biodiversity (variation of life at all levels of biological organisation)
- the means of survival (accessible food, water and soil etc)
- natural capital (resources such as forests, minerals etc)
- carrying capacity (populations that an environment can support)
- and 'eco-services' (ecosystems, goods and services)

Eco-services are natural systems that provide essential services, like air and water, decontamination, pollination, flood control, climate stabilisation, fertile soil, storm water retention, food, medical resources, and so on. When we try to substitute industrial systems for natural processes, we often use far more resources and energy than we produce. Industrial processes for example, take 10 joules of operational energy to produce 1 joule of food, and 2 kilograms of topsoil is consumed to produce 1 kilogram of corn (Kimbrell, 2002). This is clearly not sustainable. The design of development has been gradually reducing eco-services while increasing risks, such as extreme weather events or the loss of biodiversity, that is essential to a secure, diverse, accessible food supply. Our current systems were not designed to cope with the consequences of climate change, political terrorism, and global monopolies on oil and food. For example when someone plugs up the conduits that supply these fundamental resources, people die (as recently seen in Palestine and Lebanon). As civilians lose access to the means of survival, they also lose basic democratic rights and future options. In recent years, farmers have suicided in public protest to the loss of their water and/or land (ABC, 2005).

Therefore cities and buildings must become *more* than self-sufficient. We need what can be called 'design for eco-services'. That is design that creates healthy, well-distributed and reliable supplies of food, air, water, energy and biota and *increases* the ecological base.

1 Versions of this material have been presented in the author's courses and conferences. How to plan net positive regions and design net positive buildings is the subject of *Positive Development: from Vicious Circles to Virtuous Cycles* (in press).

## 3.0 How could design for eco-services actually increase the ecological base?

Some argue that if a city, development or building were designed on the model of a forest or reef ecosystem (i.e. largely self-sufficient), it would be in ecological balance with its bioregion and thus be sustainable. This is often called 'biomimicry'. However, the ability of natural systems to regenerate and evolve is now greatly impaired, as the carrying capacity of nature itself is being eroded, diminished and degraded (UNEP, 2005). So even if all buildings were designed like ecosystems, and were impact neutral, cities would still not be sustainable.

If we are serious about 'sustainability', then, it is necessary that development work increase the Earth's ecological health, resilience and carrying capacity, and protects biodiversity in order to meet even the legitimate demands of existing populations. In other words, to protect our life support system, cities must be re-designed to increase the total ecological base beyond its pre-development condition. This is inconceivable within our current frameworks of design, yet it can be done. Green buildings at best reduce some negative impacts, but they still replace nature with 'machines for living'. In contrast, design for eco-services would create 'gardens for living'. Buildings would provide the infrastructure for natural systems to function in cities.

## 4.0 With limited space, how can we increase ecological carrying capacity?

We have to change the basic nature of our human-designed systems. Presently the design of the built environment creates about half our resource flows depending upon where we draw systems boundaries (Roodman and Lenssen, 1995). We have only decades to reduce our resource flows by 90 per cent in order to achieve sustainability as the OECD has warned. Therefore, we cannot achieve intra and inter-generational equity unless we reverse these linear flows, so that cities actually support their bioregions. Until now, cities have been designed more like blue bottles than productive ecosystems. Like these poisonous jelly-fish, our cities suck up nutrients and send toxins down their tentacles, but on a global scale. We could at least reduce the ecological footprint of urban areas to a significant extent if we simply integrated natural and human functions in cities. Space for natural systems need not conflict with space for human activities, if we develop more adaptable and multi-functional design concepts. Urban areas can be 'naturalised' without extra costs (Romm, 1999). After all, there are continual renovations anyway regardless of how durable the buildings are.

Eco-technologies are already available that use natural systems to produce clean air, water and soil, and improve human and ecosystem health (Todd, 1994; Baggs, 1996; Lyle, 1994; Wann, 1996). Examples include:

- Living Machines
- vertical wetlands
- window terrariums
- multi-functional atriums
- living walls, etc (see glossary, Appendix B).

They provide eco-services while generating positive economic multiplier effects through resource reduction, waste reuse and employment.

## 5.0 Are there really any net positive technologies that go beyond remediation?

Yes, one of particular relevance to Australia is the solar pond. Solar ponds are salt pools that collect and store solar energy. Solar energy (heat) is absorbed at the bottom of a 2-3 metre deep salt pond. The solar heat that is absorbed by a dark coloured base is trapped in the bottom level of the pond, which is denser than the surface water due to the concentration of salt. The heated water is too heavy to rise and dissipate into the atmosphere. Heat at the bottom of the pond can be over 90 degrees Celsius and thus can be used for industrial processes or space heating, hot water or electricity production. This process can also produce salt as a by-product, and the heat from the solar pond can be used to dry the salt. Since Australia has serious salinity problems, solar ponds could reclaim land damaged by past mismanagement (CSIRO) and return ecosystems to a healthy condition. Solar ponds could remediate the landscape, produce economic growth and provide eco-services: they are already beginning to be developed and operated commercially. There is one proposed in Australia that will produce salt, heat and brine shrimps for stock feed, while mitigating salination or returning degraded land back into agricultural use or ecological functions. So it could be said to be productive as well as remedial (see http://www.oceanarks.org).

Buildings could also be designed to go beyond remediation to generate net positive impacts and increase ecological productivity and resilience, as discussed in *Positive Development* (by the author).

## 6.0 How is positive development different from what is called 'closing loops'?

We increasingly hear a distinction made between circular, as opposed to linear, metabolism, where wastes from one process become resources for other processes. In Cradle to Cradle it was argued that instead of closing loops we can create 'no loop' designs, where no waste is generated in the first place (McDonough and Braungart, 2002). But we might add to this a third variation that goes further. Direct action to correct past design problems could be described as a 'reverse linear system'. This more proactive approach is exemplified by earthworms: they are quite literally 'linear systems', however they perform in the opposite direction of industrial factories, as they turn wastes into resources. Earthworms are also a good source of protein in themselves, although 'wormburgers' have not really taken off yet! Arguably therefore, worms have evolved to a higher level of 'intelligent design' than human societies, which continue to turn resources into waste.

The humble worm could be said to encapsulate a net Positive Development approach. The aim of Positive Development is to take affirmative action that goes beyond remediation to create net positive ecological impacts. Good design would leave the air, water, soil, biota and people in a healthier condition than before. But net Positive Development would also add social and ecological value. With imagination some of the examples provided in Appendix C below, could be scaled up to a building or regional level.

## 7.0 Aren't 'best practice' green buildings enough to achieve sustainability?

Positive Development is only possible if we completely rethink our design goals, methods, models and processes. We cannot achieve bio-physical sustainability through what now passes for 'green building', despite dramatic improvements over past practices. Well under 10 per cent of new buildings even claim to be green. So far truly green buildings only aim to reduce negative social and environmental impacts relative to that of standard buildings; they are seldom 'resource autonomous' and almost never have positive off-site impacts. It is accepted that the operation of buildings in Australia uses roughly 20 per cent of total energy, and constructing them uses another 20 per cent (Crawford & Treloar, 2005). Moreover, new buildings are only 2 to 4 per cent of construction. So new green buildings can only reduce a fraction of the energy that would otherwise have been used in a conventional building. The resources and emissions required to replace the existing built stock with green buildings would be far too great. Moreover the 'greenness' of buildings is usually based on claims like "the building will use 40 per cent less fossil fuel energy and 30 per cent less water than typical buildings of the same kind". Being the 'biggest loser' is a meaningless standard in a city full of morbidly obese buildings. Adding 'thinner' green buildings to the existing urban skyline will not reduce the ecological footprint of the city. On top of that, many claims such as being 'carbon neutral' are supported by rather specious means, such as by counting 'offsets'.

## 8.0 Aren't offsets a good thing, or at least a step in the right direction?

Most offsets are really tradeoffs, not net positive action. Carbon neutral usually means such developments have merely included provisions to, for example, reduce the need to drive cars, provide childcare facilities or public open space, plant trees to compensate for carbon emissions, or purchase green power to reduce the increasing rate of coal-based electricity production. While offsetting resource consumption with positive social impacts should certainly be encouraged, it is not ecologically sound. Green buildings just reduce the amount of damage we plan to do; they still substitute natural capital and ecological productivity with unsustainable industrial processes. Marginal improvements upon a non-sustainable prototype lock us into manufactured environments that will drive excessive consumption and waste for decades.

Furthermore the land-use decisions made today will determine land-use decisions tomorrow, and reduce the range of substantive options available to people in the future. Without the existence of green buildings there would be less fossil fuel, land and water consumption and pollution. We need to implement what the author calls a *sustainability standard* for development. This sustainability standard would mean that an environment is more resilient, its biodiversity healthier, and its people better off *after* construction than before. A good designer should aim for no less.

## 9.0 Would achieving a sustainability standard solve all our problems?

Positive Development is essential, but of course, not sufficient: social and institutional change is also critical. The current model of development creates 'haves' and 'have nots' on a first come, first served basis. Without a fair distribution of resources, land and environmental amenities, conflict over finite resources is inevitable. We cannot hope for positive social change while the disparity of wealth and life quality continues to increase at an alarming rate. An economic system that militates against ecology and equity is simply not legitimate. Until we design a more rational economy however, built environment design could at least ameliorate these trends by improving social relationships, equity, space and resource distribution, life quality and environmental amenity.

Built environment design can make everyone better off without increasing total resource flows. Quality design does not require imported marble or gold taps. Making people better off would entail improving what we can call the *public estate*; that is, space, environmental amenity and eco-services that are accessible to and under the control of the general public. Increasingly communities are finding that the value of open space is higher than that of developed land. The Trust for Public Lands in the USA has collected many analyses of how open space increases property values and saves the community money overall (http://www.tpl.org). Governments have even had to buy back forests that were previously allocated commercial interest for exploitation (Ridgeway, 2004).

We need to re-design our planning, design and management systems to correct the past legacy of inequitable resource transfers and ecological diminution and degradation. Eco-retrofitting of both public and private spaces could improve environmental justice and life quality at no extra cost (Romm 1999). In fact, retrofitting for resource efficiency is a 'no-brainer', having been shown to pay for itself in resource savings (Heede, 1995; Edwards, 1989).

## 10.0 So development can be an improvement ecologically over no development?

Yes. I use the term 'Positive Development' to mean built environments that increase *both* the ecological base and the public estate. It would go beyond resource autonomy to generate eco-services while improving equity, generating 'positive' social and ecological offsite impacts, and providing greater access to shared public spaces and amenities. We need to recognise that Sustainability is not just about consuming less than we do now. It is not enough to 'mitigate' the impacts of future development: we need to 'fixigate' the social and ecological problems caused by the *existing* urban development. By increasing *ecological space*, cities and buildings can reverse the impacts of previous development, while fostering safer, healthier, less consumptive forms of social interaction, and increasing the life support system as a whole. An example is atria that can produce air, water and soil and provide a social space. (See Appendix C for more examples)

Ecological space is the term the author uses for the space devoted to healthy, productive ecosystems per person or square metre in a development. The horizontal/vertical area allocated to essential eco-services and habitats for biodiversity need not reduce the floor area or amenities required for human activities and functions. Moreover the infrastructure for eco-services can create very exciting architectural forms. The design and maintenance of these new ecological spaces of course requires cross-disciplinary expert involvement in architecture by ecologists, physiologists, hydrologists etc.

## 11.0 How would we measure the positive ecological impacts of development?

Our project assessment tools focus on predicting and measuring *future* negative impacts. This is impossible in a complex system by definition. We cannot for example, trace all the synergistic interactions between immune systems and toxins over time. We pretend we can by drawing 'systems boundaries' around problems to exclude unknowns and unpredictable impacts. The preoccupation with reducing negatives has caused us to forget to 'design in' positives. Ironically, it is relatively easy to measure positive ecological impacts relative to the status quo. It would be straightforward to measure improvements in air or water quality between that entering and exiting a building or site. The financial benefits of providing eco-services in building design are also easily measured. For example, we can measure the cost of mechanical air-conditioning equipment avoided. We can do post-occupancy evaluations, and/or simply check energy, water or air quality meters after construction. Alternatively, if we put a much higher price on natural resource consumption people would innovate to conserve water and energy without complex compliance mechanisms. Besides, if a design only used natural systems and healthy materials, remediated and expanded eco-services, and increased human and ecosystem health, we would only need to establish that the development was a good investment. For development approval purposes however, councils prefer to predict and quantify impacts before construction. Ecological space would provide a simple 'surrogate' or equivalence for added eco-services.

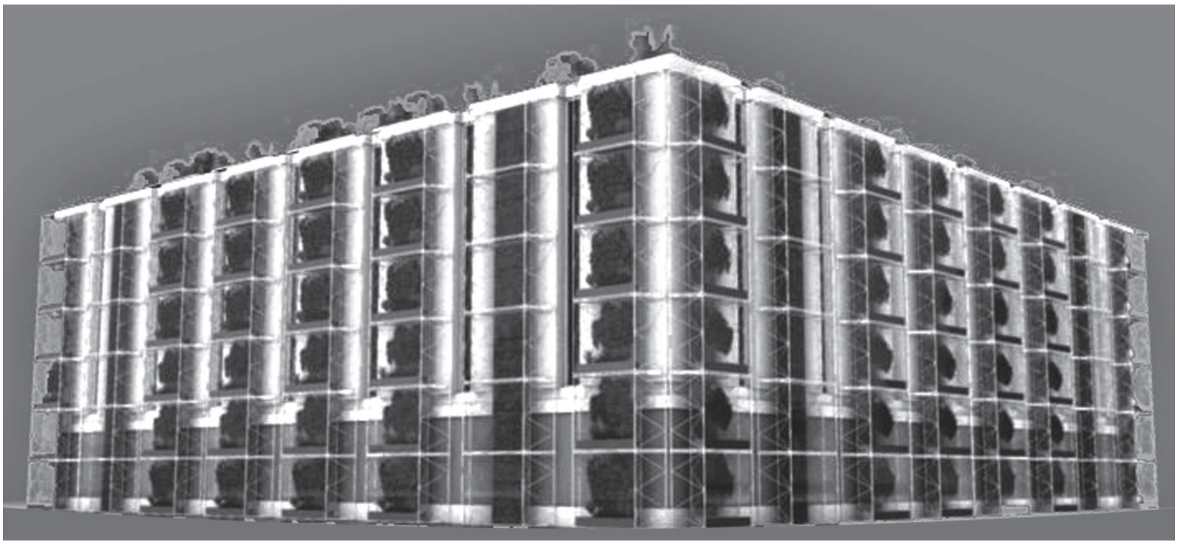
## 12.0 Doesn't ecological space just refer to a 'positive' ecological footprint?

A positive ecological footprint would only mean a reduction in negative impacts, whereas Positive Development would add ecological and social value. Like other environmental management concepts the ecological footprint is an inherently negative concept. Our environmental decision aids were premised on the idea that development must have negative impacts, thus we engage in displacement activity. Creating and refining ever more complex, competing assessment tools only increases the accuracy of the body count in our war on nature. Sustainability assessment tools can lead to 'accounting games', not direct action to improve human and environmental health by design. If the costs of inaction in fixing the environment exceed the costs of action to fix the environment, it is irrational not to act. Planners could identify and assess priorities for eco-innovation and eco-retrofitting to assist investors in solving environmental economic and social problems as a net return on investment. It would be a simple matter to award merit points for the inclusion of ecological space in existing development guidelines and criteria, building rating tools and development approval processes, and/or award schemes. Instead we make developers pay a lot extra for green building ratings or 'stars'. We do not put 'minus stars' on non-green buildings. If we labelled cigarettes the way we label buildings, people might start smoking 'lite' cigarettes to improve their health.

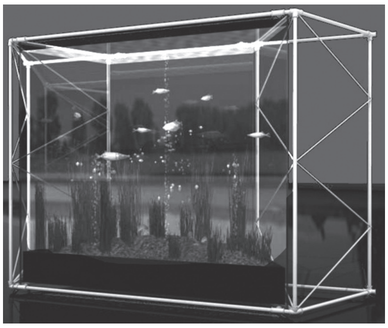
## 13.0 So how could we create extra incentives to speed up Positive Development?

Removing current disincentives that pervade development control systems and industry practices would be enough. There are also many possible incentives that would stimulate eco-retrofitting at no cost to society. For example, to increase urban density without using more land, the author previously proposed the incentive of allowing first floor units to be added to existing single level suburban development, but only where both dwellings are converted to at least

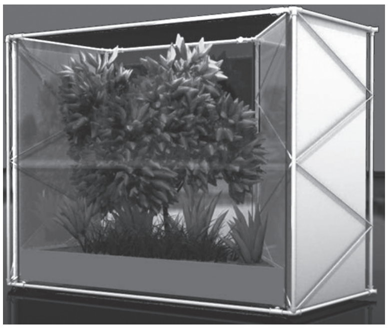
be 'resource autonomous' (Birkeland 2004, 2005). Bonus development rights such as additional floor area could be granted to developments that improve ecological conditions on and off site. The additional rental income and capital value through such retrofits would provide a strong investment incentive.
Years ago the author developed an incentive scheme in San Francisco that allowed exemptions from the building envelope (i.e. more generous floor area, set back and height limits) for sunspaces, rooftop or window greenhouses, or other features that provide ecological value (Birkeland, 1977). Mortgage systems can also provide incentives for eco-retrofitting or other developments that provide ecological space. Some companies offer lower mortgage rates for energy efficient homes because of the resultant increased effective income of the occupants. Trading mechanisms such as transferable development rights could also be implemented to encourage Positive Development.



Possible addition of living walls to existing building shown below



**Aquarium module –**
for food production



**Terrarium module –**
for soil and plant development

**Existing building –**
shown before living walls are added

Most living walls only provide air-cleaning functions, and most vertical wetlands only filter water. Autonomous living walls are generally non-structural and single function as well, tending to be monocultural. In contrast, a green scaffold would perform many eco-service functions. It would be of modular design and demounted to allow for future adaptation. Depending on site specific factors, the exterior structure could contain:

- louvers, blinds and/or pergola structures to support vines and provide shading
- mirrors, light shelves and/or skylights to direct light to the interior
- atriums for solar collection and special functions, 'deconstructing' the exterior
- terrariums also providing insulation
- thermal rock storage (Trombe walls)
- vertical wind turbines integrated with the architecture
- solar stacks and shower towers integrated into the vertical shafts of the space frame
- nesting areas for local birds and animals that can be viewed from inside
- sail and shade cloths designed for thermosyphoning as well as shade
- walkways and/or decks in parts of the green scaffolding for circulation, work spaces, or balconies
- vertical landscapes for water and air purification
- aquaponic food production, or fish producing nutrients for plants
- ant farms and butterfly breeding areas for environmental education
- integrated exterior sprinklers for cooling and fire protection
- canopies to collect the humidity from the air in order to water the planters

**Figure 1. 'Sample' of building retrofitted with green scaffolding**

## 14.0 How would such trading schemes for ecological space work in practice?

Suburban homeowners could sell rights to develop part of their property (courtyard, entry, roof, etc) for urban food production, lease facade and roof spaces for solar electricity generation, or, as a community, reclaim streets for social and ecological functions. By de-coupling ecological space from a property (like renting billboard space on a building), 'eco-retrofitting banks' or other businesses could develop these ecologically productive spaces. Banks could then sell credits to developers that are seeking enough 'points' to acquire development approvals from local authorities. This would be similar to wetlands banks that have existed for some years, where wetlands are created or restored, and the acquired credits sold to developers. Of course many such artificial wetlands are not as ecologically resilient and productive, as natural ecosystems, and species cannot be replaced once extinct.

Urban ecological spaces, in contrast, do not replace ecosystems, they create new infrastructure to support new eco-services. The development of policies and knowledge systems are needed to assist in increasing the ecological base of the city and region as a whole. The conventional approach of squeezing up cities in the hope that public transport will come, does not in itself reduce the ecological footprint or resource flows of cities (Mees, 1997). It just squeezes out the poor and nature. By naturalising cities, design for eco-services would increase the quality of life and natural resource security, and therefore attract investors, businesses, residents, tourists and nature back into central urban areas.

## 15.0 Conclusions

'Green' designers have tended to adopt fundamental negative preconceptions from the environmental management fields. Our tools assume tradeoffs are inevitable and do not attempt to reverse the impacts of past development, let alone increase carrying capacity of the planet. Architecture should add value to the social and ecological support base. Sustainability requires implementing systems that do not yet exist, not just measuring, mitigating and monitoring existing prototypes. Of course design solutions must work within the given political context, industrial realities and market system. They must also fit into the existing physical configuration of land use and transportation systems. But in these contexts what first appears to be the cheapest design solution, because it fits the sub-optimal systems context and current economic framework, is often not very rational or efficient from an ecological and long-term perspective.

Through good design, development can add value to the ecology and society. The market cannot do this; it adds glitter and litter. Although it supposedly fosters eco-efficiency if unfettered, the market's regard for human resources is 'lean and mean'. On the other hand the market has been profligate with land and natural resources. After all, there is no reason to increase efficiency, or to change the *modus operandi*, if one is doing well through cheaper access to resources, transport and labour and the elimination of competition.

Only by design can we create Positive Development. Ecological space exemplifies just one of the ways that we can create incentives for and measure Positive Development.

## Appendix A: Glossary of new terms

**Design for eco-services** refers to the integration of natural systems with the built environment to increase the 'ecological base' (life support functions) by creating the infrastructure for eco-service, in place of the current target of reducing impacts of development relative to standard buildings.

**Eco-innovation** is an institutional or technological solution that improves human and environmental health, well-being and equity while radically reducing resources (i.e. whole systems efficiency), by utilising natural systems that replace 'unnecessary' machines or products.

**Ecological base** is an umbrella term for natural capital, biodiversity, ecosystem goods and services, ecological health and resilience, bio-security, etc. It represents the life support system and 'means of survival' which if accessible and under public control, can be called the 'public estate'.

**Ecological space** is the effective ecological area provided in a development. It is a measure of positive impacts like air and water cleaning, natural heating, cooling and ventilating in contrast with the 'ecological footprint', or negative impacts that can only be minimised.

**Eco-retrofitting** means modifying and 'greening' urban areas to improve environmental and human health while reducing resource depletion, degradation and pollution. The aim would be to achieve a 'sustainability standard' – net positive improvements over existing conditions.

**Eco-services** is short for functions and services provided by natural systems like air and water decontamination, pollination, flood control, climate stabilisation, fertile soil, storm water retention, biodiversity, etc.

**Green scaffolding** would add a second skin to an existing building to support the urban ecology, increase the building lifespan, and expand the effective interior space (where codes allow). It could include solar stacks, shading louvers, shower towers, Trombe walls, vertical composing, light shelves, etc.

**Positive Development** would meet or exceed established ESD (Ecologically Sustainable Development) criteria – but also reverse the impacts of current systems of development, create eco-services and increase the ecological base and public estate.

**Public estate** refers to the means of survival like food, land, air, water, soil and eco-services that are accessible to the public. As civilians lose access to the means of survival, they also lose basic democratic rights and future options.

**Sustainability standard** requires an improvement in human and ecological health over what would have been the case if the development was not built. This means the ecological base would be more extensive and resilient than before development occurred on the site.

**Sustainability** (with a capital S) as used here, means that all future generations will inherit substantive environmental and democratic rights, control over the means of survival, an increased ecological base, and genuine social choice (i.e. not the 'substitution' of manufactured capital for future natural capital).

## Appendix B: Standard terms

**Ecological footprint** is the equivalent area of land and water needed to produce the supplies from around the world to feed, clothe, house and entertain urban dwellers in a given area. Currently a city's ecological footprint is many times greater than the geographic footprint.

**Living Machines** are self-contained networks of (solar powered) ecological systems designed to accomplish specific chemical functions by supporting micro-organisms that eat toxic wastes. They also generate and support gardens and fishponds at the end of the remediation chain. (See http://www.oceanarks.org)

**Living walls** are walls, room dividers or screens that provide space for plants within their structure for air cleaning functions and visual amenity. Their design can accommodate windows or openings as well, and can be structural or temporary, indoor or outdoor.

**Resource autonomous** buildings are self-sufficient in the production of their own energy, clean the air, grey water and sewage on site, and use healthy materials (e.g. rammed earth instead of fired brick). They aim to be impact neutral, not net positive.

**Transferable development** rights are used in city planning regulations to allow developers to exceed the allowable floor area or height limits on another property, as compensation when their development rights are restricted by new regulations (e.g. to create an historic district).

**Vertical wetlands** are a series of containers of plants, soil and rocks suspended from ceilings, or hung on walls, through which water drains either (from the roof or greywater from the building). These 'hanging gardens' filter the water and clean the air while feeding plants.

**Window terrariums** are attached greenhouse windows that contain planters (or even microhabitats for frogs or caterpillars) that provide air cleaning and conditioning functions. They can be retrofitted onto existing buildings and can provide visual interest.

## Appendix C: Examples of net Positive Development

There are probably no buildings that could qualify as net Positive Development yet (i.e. beyond resource autonomous in all respects), but there are many ideas that could contribute to such buildings. The author is working on the design of the proposed Australian National Sustainability Centre to demonstrate net Positive Development.

Some examples of potential positive development concepts include:

**Green space frame wall:** This is the author's term for multi-functional structural walls for new buildings. Like 'green scaffolding', these frames of vertical trusses and glass could house Trombe walls for passive heating, solar chimneys and/or shower towers for cooling, vertical landscapes for air and water purification, vertical composters, mirrors, louvers, light shelves, as well as aquaponics, terrariums, nests and butterfly breeding cages. In some areas they could expand out to accommodate atriums, walkways or balconies.

**Suburban fire prevention:** After bushfires, the response of authorities is often to clear native bushland from around suburbs. This can exacerbate problems of erosion, flooding, siltation, dust, and air pollution. An alternative is to create landscape arbours containing integrated sprinklers, hidden cisterns for water storage or chain-of-pond water recycling systems that also support wildlife habitats and social or recreational activities.

**Resources from waste:** Organic waste in rooftop Living Machines on offices or homes can be turned into fertile soil to support urban agriculture, reduce food transport, provide thermal insulation, reduce the urban heat sink effect, and so on. Heat from rooftop greenhouses can be circulated through the building, and a careful selection of plants can target specific pollutants, to improve air quality. Natural processes can be harnessed for human use without competing for space with people (http://www.oceanarks.org).

**Micro-labourers:** Bacteria can be utilised for many economic and environmental functions such as the bioremediation of toxic wastes including sewage, petrochemical contamination and oil spills, to improve plant growth in desert conditions, to restore deteriorating historic buildings and even produce lighting and energy. Fungi have been used to rehabilitate logging roads by stopping siltation and produce non-toxic agricultural and domestic poisons. Mushrooms can transform some toxic substances into harmless ones, becoming safe to eat after they finish their work (http://www.fungi.com).

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## Biography

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