Design for Ecosystem Services
A New Paradigm for Ecodesign

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In the context of the increasing rates of resource depletion and degradation, the built environment must be redesigned to literally *reverse* the negative impacts of existing patterns of land use and development, improve human and environmental health, and increase natural capital (ie increase renewable resources, biodiversity, ecosystem services and natural habitat). To do so, we must transform our design and construction processes well beyond 'best practice', which merely aims to reduce adverse impacts relative to conventional buildings. What are currently regarded as 'ecological' design goals, concepts, methods and tools are not adequately geared toward the systems design thinking and creativity required to achieve this challenge. An entirely new form of design for development is required.

This paper presents a new paradigm for 'eco-development', aimed at transforming development itself from an environmental menace into a 'sustainability solution'. Eco-development is used here to mean development that achieves *net positive impacts* over its life cycle, by increasing economic, social and ecological capital. The aim of the current research project is to prove eco-development is possible, if it creates the space and conditions for self-sustaining ecosystem services and biodiversity in the urban environment. This paper flags some of the methods and tools needed to achieve this aim: a new approach to design criteria, standards, benchmarks, assessment, ratings, rewards, reporting, and design methods. These are part of an ongoing research agenda and are developed further in other papers.

What is wrong with 'best practice' environmental design?

Currently, the 'greenist' buildings really only attempt to replace ecosystems with mechanical impersonations (which would be no small achievement). To generate an increase in environmental health and natural capital, however, the built environment must not only (a) be retrofitted on the model of a living landscape to restore and detoxify the natural environment, but also (b) enable the natural environment to increase the essential life support functions that are currently undermined by status quo development. To increase the spatial and biophysical conditions for ecosystem services in urban areas (especially in an era of diminishing land availability and escalating land costs) requires the integration of buildings, infrastructure and landscapes, and the creative, multi-functional use of space. This goes against the conventional reductionist wisdom that boils environmental problems down to energy and greenhouse gas reduction and water (sometimes with air quality and other issues thrown in), and thus sees space as costing energy (eg through higher transport and urban sprawl). A paradigm shift is therefore a prerequisite to redirecting built environment design toward eco-development.

Box 1: Key words defined

Sustainability means to improve life quality for all (ie present and future generations, and other species) within the limits of the earth's carrying capacity and natural rate of replenishment. This will require reversing environmental impacts and increasing natural capital through the (re)design of the built environment.

Built environment or **development** refers here to the human made physical context - infrastructure, landscapes, products, buildings, factories, cities, etc. The design of the built environment affects human development and potential, but the focus here is on physical spaces and structures.

Sustainable development requires decisions and actions that keep future development options open - rather than making irreversible decisions. Development is sustainable only where it increases net natural capital, reduces overall resource flows and meets the eco-development criteria listed below.

Ecological retrofitting refers to renovations of existing buildings that aims to 'green' the whole structure, site and/or area to the greatest practical extent, including being 'resource autonomous' and providing its own 'ecosystem services'.

Ecosystem services is the provision of basic life support functions (like air and water decontamination, pollination, flood control, climate stabilisation, fertile soil, storm water retention, biodiversity, etc) through the operation of natural systems. To be sustainable, urban development should provide its own ecosystem services.

Resource autonomy is where a building or settlement is self-sufficient in the production of its own energy, clean air and water, and treats grey water and sewage on site – not imposing a net operational cost upon the bioregion.

Bioregion is a region whose (fluid) boundaries are defined by bio-physical and cultural features, such as watersheds, deserts, rainforests, etc (rather than political jurisdictions or administrative boundaries).

Eco-development is that which meets ecologically sustainable development criteria - but also increases natural capital by creating the conditions for self-sustaining ecosystem services, natural habitat and biodiversity. It has net positive resource flows and improves human and environmental health by reversing negative impacts.

Systems Mapping traces the transfers of energy and materials in and out of an urban area (or farm, house, factory, region etc), and the transformation of those resources within these systems to find leverage points for change.

What does sustainability mean in the context of the built environment?

Among other things, 'sustainability' means that our natural life support systems are not to be depleted, degraded, or distributed inequitably over the long term. Taken to its logical conclusion, sustainability cannot be achieved unless the built environment creates the biophysical conditions in which sustainability can occur. Thus, for example, urban areas cannot continue to bulldoze ecosystems or suck up regional resources like a giant vacuum machine. Instead, resource flows between populations in urban and regional areas would need to be in some form of 'balance' over time - as one symbiotic system. To achieve a better balance in resource flows, systems of development (construction, farming, forestry, etc) would theoretically only need to be re-designed on 'resource autonomy' principles. However, given that development is currently causing a resource deficit instead of a balance, true sustainability requires that new development do better than 'zero waste'. Further, existing development needs to be retrofitted so that it is truly 'regenerative'. A built environment can be 'net positive' if it improves human and environmental health by reversing negative impacts and increasing natural capital and biodiversity.

Surely net positive design is an impossible state to achieve?

Using bio-conversion technologies, already existing in the form of living machines, for example, we can increase the biological health of the soil and reverse global warming without harmful chemicals, or bankrupt concepts like geo-sequestration (Jehne 2005). Business as usual is far more impractical and unrealistic than sustainability, when looked at from a distance. Even what currently qualifies as 'green' development is largely in direct conflict with our life support systems. We are trying to escape the womb by cutting off our umbilical cord. Net positive development is only achievable with an entirely new approach to design: in addition to meeting the standard sustainable development criteria that address social, environmental and economic well-being, therefore, eco-development would need to meet the minimal criteria in Box 2 [A more detailed criteria is provided in *Design Method*].

Box 2: Criteria for eco-development (physical only)

- exceed 'resource autonomy' (ie self-sufficient energy production, water and waste treatment) to actively restore the indigenous ecology - as we already exceed carrying capacity;
- integrate and increase 'ecosystem services' with development (ie provide conditions and space for the production of healthy air, water, soils through natural systems);
- foster natural habitats and 'biodiversity' (ie variety of suitable symbiotic species and ecosystems) in urban as well as regional areas;
- reduce land coverage while increasing natural capital (renewable energy, ecosystems and biodiversity);
- replace fossil with 'solar resources' (ie wind, sun, biobased materials).

Why focus on development instead of direct environmental protection?

We need to tackle causes, not symptoms. We cannot protect the environment 'downstream' unless we change the nature of development 'upstream'. Until recently, environmental managers have focused on the environmental impacts (effects), rather than the design of development (causes). This 'end-of-pipe' thinking is finally being addressed, as evidenced by the many professional groups that have formed over the last decade to champion green building. In general, however, people still do not appreciate how the design of the built environment is central to social, economic and ecological problems. Perhaps more significantly, few environmental professionals seem concerned about how environmental planning and design decisions made today lock us into unsustainable options tomorrow. Even so-called 'green' development is limiting our future social choices, which is unfair to future generations. A basic tenet of sustainability is that future generations should have the same level of life quality, environmental amenities and range of choices as 'developed' societies now enjoy.

Aren't we addressing development issues adequately through eco-efficiency?

Clean and efficient industry is important, but it is not enough to achieve sustainable development (zero waste) – let alone net positive impacts (eco-development). There have been efficiency gains in production, but total resource flows through development are still increasing. That is, we are producing and wasting more and more stuff. A huge portion material and energy produced in the industrial world ends up as waste (see Hargroves and Smith 2005). This is in large part because the current design of the built environment (infrastructure, buildings, products, landscapes) causes excessive resource usage before, during and after construction (in some places, for example, buildings use 50% of timber, 40% of energy, 50% of concrete, etc). Furthermore, design pre-determines a significant portion of the downstream demand for materials and energy in industry, even if they are produced more efficiently. This leaves consumers as well as manufacturers with limited options for reducing consumption. We cannot get to sustainability from where we are now: systems re-design is required to achieve an adequate reduction in total resource flows.

How can the demand for more buildings be met while reducing resource flows?

We can increase the amount of space for human activities in urban areas while reducing and even reversing impacts, but only if we incorporate multi-functional spaces that increase natural, social and economic capital. So far, there are probably no developments that are net positive. However, there are now many (though isolated) examples of technologies that dramatically *reduce* resource consumption, such as 'resource autonomous' housing developments (that generate their own energy and treat their own waste), building retrofits that increase worker productivity and health (Romm 1999), and appliances that operate on direct solar energy. In other words, there are many 'eco-innovations' to draw upon in built environment design; that is, products or services that radically reduce resources while improving the economy, environment and life quality (Box 3). However, while there are eco-technologies, living machines, fungi, etc, that turn wastes and toxins into saleable products, they are seldom integral to the design. There are partial exceptions, such as the 60L building retrofit in Melbourne which includes a living machine in the central atrium (a building in Oberlin College, Ohio, houses a Living Machine in a separate building).

Box 3: Examples of Eco-innovations

- **Toxins**: Waste dumps are being cleaned up by a series of microbes, mushrooms and earthworms - and the end products include toxin-free potting soils (www.oceanarks.org).
- **Oil spill**: Oils spills are being cleaned up with bio-solvents made from vegetable oil (www.cytoculture.com).
- **Soil**: Nutrients and soil conditions are being increased by farming practices that find a synergistic mix of crops and animals (www.leopold.iastate.edu).
- **Biodiversity**: Agricultural systems are being developed that integrate farming and ranching with natural ecosystems (www.watershedmedia.org).
- **Water**: Waste water is being decontaminated by a series of 'living machines' containing ecosystems that produce healthy fish or plants at the end of the process (www.oceanarks.org).
- **Air**: Indoor air is being cleaned by a careful selection of plants, and/or 'planting walls', and roofs are being designed to support gardens to increase usable space, insulation and food. (www.zone10.com/tech/NASA).
- **Food**: Organic and intensive farming practices are producing far more food per area of land than the mono-cultural crops produced by agribusiness (www.fatalharvest.org).
- **Pests**: Effective non-toxic insecticides are being produced from mushrooms to replace harmful agricultural and domestic poisons (www.fungi.com).
- **Energy**: Wind power is growing at an extraordinary rate, despite ongoing subsidies to coal-fired electricity (www.anzses.org).
- **Buildings**: Simple cost-effective changes to new or existing buildings have reduced the operating energy demands of buildings by up to 90% (www.natcap.org).

Where would we find the space required for these ecosystem services?

To create more space and reduce the colonisation of natural areas, we can eco-retrofit urban environments when they need modifications or upgrading anyway. If urban space were not treated as a problem, it could become a solution. We are eliminating this critical resource in urban areas, on the assumption that squeezing out open space in cities will take the pressure off the hinterland. However, net resource flows can be higher per capita and per land area in high-density urban development than in suburbs - it all depends on the design, construction methods and materials. Given the growing shortage and cost of land, an alternative to conventional planning and design that wastes and/or eliminates space is the multi-functional use of space to increase natural, social and economic capital. When we instead promote high-density development that excludes passive solar design, urban biodiversity and ecosystem services, we are trying to substitute natural capital with other forms of capital, such as financial, manufacturing or built capital. This approach does not enhance fundamental systems health [See *Urban Form*].

Why aren't existing eco-innovations being used in built environment design?

We should be applying these eco-innovations now, but we are trained to measure problems, not implement solutions. For optimum results, eco-innovations need to be integrated into the whole urban fabric from the ground up. The key to eco-innovation in built environment design is an integrated, 'whole systems' design approach. This is because incremental change in a complex design like a building or city often causes sub-optimal results (Romm 1999). 'Borderless' whole systems thinking can generate synergies between ecological, psychological, cultural, economic and social dimensions – in lieu of trade-offs. In fact, recent research has shown that the 'greener' the building, the more efficiency gains per dollar. There have been many examples where big changes have led to far greater economies than superficially less costly or minor changes, as documented in *Factor 4*, *Natural Capitalism and the Natural Advantage of Nations.* To create innovative environments, we need new institutions, criteria, methods and assessment systems that stimulate systems design thinking, not just efficiency.

Wouldn't a shift to an ecological design paradigm be adequate in itself?

Not really. The concept of net positive design (ie design for ecosystem services) represents a potential new stage in the evolution of environmental management paradigms beyond: (a) 'compliance' or end-of-pipe design, (b) 'eco-efficiency' or front-of-pipe design, and even (c) 'zero-waste' or closed loop design, where waste is designed completely out of production and consumption systems. The idea of moving *beyond* 'zero waste' is not a concept that is easily grasped, even among sustainability experts. Even ecological design has been, to some extent, shaped within old paradigms that were premised on the idea that negative impacts are an inevitable cost of development. If people understood that, with better design, buildings could be net positive, there would be fewer excuses - and design awards - for developments that are still ultimately ecologically, socially and economically cannibalistic.

Isn't basic change starting to happen with all the new 'green' buildings?

There is still a tendency to confuse energy and greenhouse gas efficiencies with 'green development', even among some green building advocates. Further, the term is still applied to buildings that merely have fewer impacts than the depressing norm. Fundamental sustainability issues include a very wide range of considerations, from the elimination of fossil fuel use to the multiple-use potential of public spaces in, on and between buildings to achieve ecological regeneration. Design goals have been narrow, because the traditional impact mitigation paradigm perpetuates the rationalisation that buildings and cities are independent of nature. In fact, few have even tried to design buildings that reverse the negative impacts of existing development - on or off site. Radically different design criteria, methods and tools are needed to shift the design paradigm beyond impact reduction to net positive development: a first step is the explicit articulation of a new paradigm of 'eco-development'.

How would one distinguish this new paradigm of eco-development from eco-design?

There are no texts that explain the idea of 'design for ecosystem services' as such, but there are many excellent books that canvass similar ideas (eg Lyle 1999 on regenerative design, McDonough and Braungart 2002 on no-loop design, and Todd 1994 on biological design). To use an analogy, in the health care fields we have moved (conceptually) from (a) alleviating symptoms, to (b) curing illness, to (c) preventing disease, to (d) improving health. Development control is still largely at the first stage - mitigating impacts (ie alleviating symptoms). To stretch the analogy, we are still counting on cryogenic solutions instead of healthy lifestyles. Design for ecosystem services could be described as: design that works to *reverse* impacts, eliminate externalities and increase natural capital by supporting the biophysical functions provided for by nature in development itself - to restore the health of the soil, air, water, biota and ecosystems.

How exactly can buildings provide ecosystem services then?

They cannot. Complex natural systems are currently beyond our comprehension, let alone our ability to replace. Structures that emulate ecosystems services still squeeze nature out of cities. A truly green building would create the framework, physical support and space for natural ecosystems to evolve, sustain themselves and provide basic life support systems over the long term. In this way, buildings can enable nature to continue to, for example: support biodiversity and productive ecosystems; treat organic wastes; sequester carbon; control pests; produce food, fibres, and pharmaceuticals (eg antibiotics); help regulate the local (and global) climate; develop fertile soils and prevent erosion and sediment loss; purify air; store and recycle water; and alleviate floods, drought and storm water runoff (see Daily and Ellison 2002 on ecosystem services). Of course, building design concepts and eco-innovations can also be *inspired* by natural systems. There are books that suggest how buildings can draw ideas from natural systems, such as *Biomimicry* (Benyus 1999) and *Wildsolutions* (Beattie and Erlich 2004).

So we can distinguish 'nature as model' from 'design for ecosystem services'?

Providing the conditions for ecosystem services is different from using nature as a model. An example of a building technology modelled on nature is natural air conditioning based on the principles of termite mound construction. Cool air is drawn from a shaded or underground tunnel and hot air rises through 'solar chimneys'. This is an increasingly common design technique [See *Solar Core*]. Another is the new CH2 building in Melbourne that is modelled, in a sense, on the biological functions of an organism or plant. While some designers have drawn analogies between their buildings and ecosystems, plants or other natural systems, there is a danger of using nature simply as a metaphor for mechanical systems. Living or working in buildings designed to be 'mechanical trees' might be an improvement over buildings designed as a 'machines for living', but they would not allow for biodiversity, natural habitats and ecosystem functioning.

How would we begin to reverse the impacts of existing development?

The easiest and most cost-effective way to reduce existing resource flows or make improvements over existing conditions is through ecological retrofitting; that is, modifying the existing urban environment to improve overall human and environmental health. Only about 2% of the building stock is new, so new 'green' developments have relatively little overall impact on total resource flows. More significantly, the costs of retrofitting can be regained from the resource savings and capital gains, so it is a 'no regrets' strategy [see *Business Case*]. Most ecological design concepts, however, are adaptable to both new and existing development. For example, many modern buildings provide sunspaces or atriums to support the heating, cooling and ventilation systems, to provide plants for cleaner air, and places for people to relax, meet or have lunch. Such spatial design concepts could be radically extended to provide living spaces that maximise (not just supplement) climatic and social functions. Currently, most assessment tools do not measure actual performance. A critical step forward is to incorporate appropriate sustainability criteria and indicators in post occupancy evaluation (POE).

What kind of indicators could reflect natural and social capital?

Indicators need to reflect fundamental systems health, such as those in Box 2. Generic systems criteria such as the 'Natural Step', tend to be couched in negative frameworks: eg ensure that 'nature is not subject to systematically increasing degradation by physical means'. Instead, we need signposts toward sustainability, using measures of 'genuine' progress. Genuine Progress Indicators ('GPI'), for example, provide a starting point for developing positive design criteria and indicators, because they attempt to measure well-being (ie personal, social and natural capital) not just activity recorded in the market (see Hamilton 2004). Such signposts could refocus design on creating new, positive conditions that reverse the collateral damage caused by conventional urban form. Checklists and minimalist requirements are less helpful in stimulating creativity than indicators based on maps of total resource stocks, flows and relationships. Currently, we reward the predicted performance - instead of post occupancy performance - based on narrow, isolated variables, like CO_2 emissions.

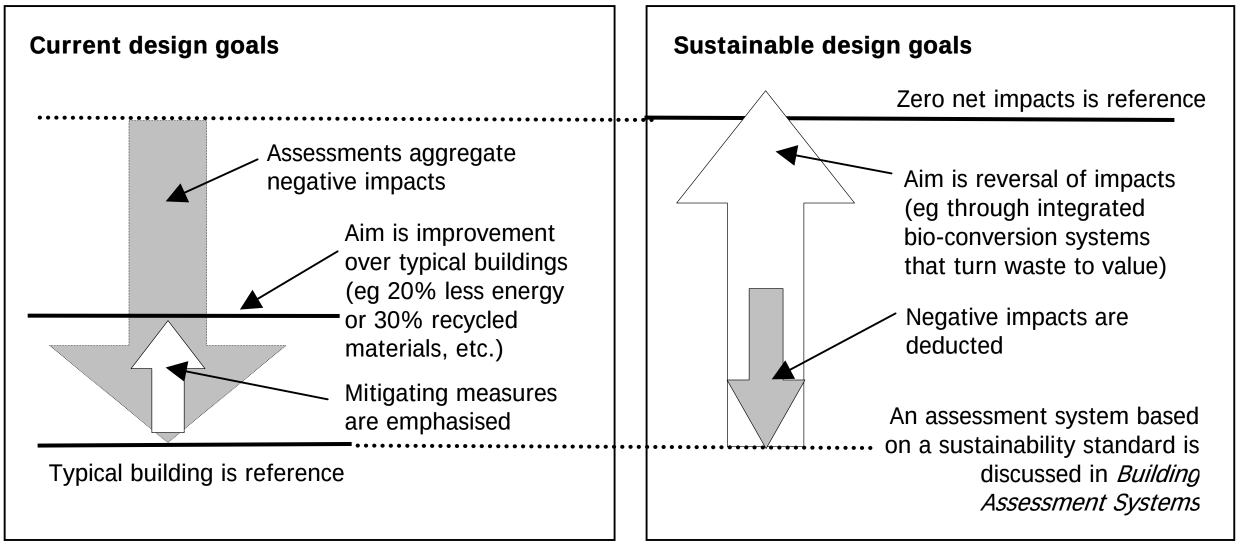
Why aren't existing 'green' design indicators and assessment tools adequate?

There are myriad eco-design guidelines, checklists and assessment tools available today, but they tend to promote marginal improvements upon an unsustainable development model, not sustainable development (eg increasing energy efficiency but not eliminating fossil fuel use). These tools also tend to lock in old design norms because they draw data from conventional construction processes, products and designs, or rely on existing or contemplated designs to predict and estimate future impacts. Given the financial benefits of green building, it is clear that the current range of 'green' criteria, models, methods, and institutional mechanisms are simply not doing enough to stimulate either eco-innovation or an integrated whole systems approach. For example, while the star rating schemes encourage competition by pushing the 'mine is bigger than yours' button – we are still competing for the tallest (resource-intensive) skyscrapers as well [see *Building Assessment Systems*].

So what kind of assessment tool would overcome the problem?

Rather than tools that compare the predicted impacts of design against those of existing buildings, developments should be assessed in relation to a 'Sustainability Standard'. A Sustainability Standard would require positive environmental flows over time, and a net increase in social, economic and natural capital. What is called ‘best practice’ generally does not meet this sustainability standard because, for example, it is usually based on claims like '50% less VOCs, CO2 emissions and operating energy than usual' - when it is technically possible to have no VOC emissions, concrete that absorbs CO2, and net positive energy production. Rating and assessment tools have many of the same problems as impact assessment processes (see Birkeland 2002). They are also concealing trends in total resource consumption when publicity focuses on how much better a project is over others and not mentioning cumulative impacts. The difference in aims is illustrated in Box 3.

Box 3: Building assessment tools



Don’t you need a baseline or minimum standard based on typical buildings?

The baseline would be the existing site or building conditions (rather than standard buildings). This benchmark recognises that every site is different and every building project has different functions in relation to the site and surrounding development conditions. Seeking improvements upon existing site conditions (eg the health of air, soil, water, biota and natural habitats) would favour retrofitting and remediation projects [See *Business Case*]. It would also encourage initiatives such as restoring the health of the environment beyond the site boundaries - for which there is currently inadequate incentive. If, for example, a surrounding area is a brown-field (contaminated) site, or a run-down sewage treatment facility or abattoir, the new development should get credit for converting the waste from the neighboring areas into a useful or marketable resource. This has been achieved in industrial ecology projects, but not in urban developments. The next step is to credit developments for savings in externality costs.

Why change from ‘best practice’ to a ‘Sustainability Standard’?

Requiring developers/designers to pretend to trace all the repercussions in life cycle terms is not as important as educating and disseminating ways to ensure that the air, water and soil produced on site is healthier than that entering it. To shift the emphasis from measuring the damage of designs to generating alternative systems solutions, the assessment system would be based on positive criteria and require a systematic exploration of ecological design options. In a Design Report, designers would explain why they could not achieve a reversal of ecological impacts (against the criteria in Box 2); that is, design processes undertaken to address this, and reasons for not using available eco-technologies and/or design concepts. Proponents would therefore have to examine their untested assumptions, such as “sustainable design costs more so we won’t consider it”. This would also enable assessors to suggest alternative solutions whereas, in most places, proposals that meet a minimum standard are automatically approved. Conceptual design alternatives, usually geared to winning competitions through graphics, should instead be generated by mapping resource flows and externalities at the schematic analysis stage, before design concepts are selected. In other words, (retrospective) accounting should be subsidiary to (prospective) design.

So the reporting would require measurement, but of flows instead of impacts?

Design for ecosystem services and net impact reversal requires an understanding of total resource flows using some form of systems mapping. However, the amount of data and measurement that is appropriate would depend on the scale and complexity of the project (as is usually the case in impact assessment). The important thing is that the tools fit the nature of the design - whole systems thinking. Ecological design tools must look beyond impacts, inputs and outputs, to environmental flows through the existing or proposed development, and between that development and the surrounding region. Employing systems mapping methods in the early stages of the design would facilitate the improvement of the ecological (as well as social and economic) conditions of the site and wider region. This would mean analysis would feed into design, whereas previous assessment tools require the existence of design ideas to measure [See *Design Methods*].

How can a design improve existing site conditions or the building context?

The premise of the research project is that long-term social and economic sustainability can only result from design and innovations that are ecologically sound; that is, efficient from a whole systems perspective. It is not enough to be economically and ecologically efficient within the client's brief alone. To move toward sustainable development, a building, city or settlement must be designed to interact with and improve its context, well beyond the exterior envelope of the building or product boundary (Birkeland 2002). In summary: it is not enough to redesign a product (or products) - a design should contribute to redesign the entire industrial system (eg construction, farming, forestry); it is not enough to eliminate waste and toxins - a design should contribute to reducing the total flow-through of materials and energy; it is not enough to restore environmental quality - a design should contribute to the creation of ecosystem services and urban open space for contact with nature, food production, biodiversity and ecosystem services it is not enough to reduce the damage relative to standard buildings - a design should reverse the impacts of existing buildings. In short, a design project should be re-conceived as a leverage point for system-wide change in the urban and regional context.

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