**BEDP ENVIRONMENT DESIGN GUIDE**

# Ecological Waste: Rethinking the Nature of Waste

**Janis Birkeland**

***Summary of***

# Actions Towards Sustainable Outcomes

## Environmental Issues/Principal Impacts

- Waste needs to be understood as a design issue. Most waste is 'designed in' long before products reach the construction site or building user. Designers should consider the following:
  - Recycling creates jobs and profits, and saves money and resources, but only addresses post consumer waste, a tiny fraction of total resource flows.
  - 'Cleaner production' and 'eco-efficiency' measures are important in the mix of solutions, but represent only process improvements to a non-sustainable development prototype.
  - Industrial symbiosis projects enable one industry's waste to become another's resource, but do not reduce demand on living environments for raw materials.
- Design could do far more than reduce pressure on the environment by reducing waste and resource flows; it could increase the health and resilience of the ecological base.
- The 'rebound effect' can probably only be addressed by designing built environments that create a rich range of low-impact choices.

## 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:*

A three-pronged approach to designing waste out of the system would help bring an appreciation of the 'opportunity cost' of poor design.

**Step 1:** Think seriously about 'designed waste', which is the duplication, disposability, planned obsolescence and wasteful end purposes to which resources are put through poor design.

**Step 2:** Develop new concepts like 'ecological waste' that value the environment as a living thing, not just a collection of resources or inputs and outputs. Ecological waste accounts for the time and space it takes for the source of materials, or ecosystems, to regenerate.

**Step 3:** Assess and prioritise innovations and investments in terms of their potential to improve ecosystem and human health, using a hierarchy of eco-innovation.

## Cutting EDGe Strategies

- Ensure construction by-products are converted to resources and not waste.
- Develop building prototypes that use far less materials and energy in relation to the functions and services that they provide.
- Weigh in the costs of inaction and opportunity costs of poor design, don't just assess the negative impacts of future developments.

## Synergies and References


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- *BEDP Environment Design Guide:* GEN 4: Positive Development: Designing for Net Positive Impacts
- *BEDP Environment Design Guide:* GEN 21: Waste Minimisation and Resource Recovery
- *BEDP Environment Design Guide:* GEN 29: Waste Minimisation and Building Design Professionals
- *BEDP Environment Design Guide:* GEN 30: Project Waste Management Plans – Costing and Quantifying Construction Waste
- *BEDP Environment Design Guide:* GEN 31: Education for the Next Industrial Revolution – Teaching Resource Efficiency and Effectiveness in Environmental Literacy
- *BEDP Environment Design Guide:* TEC 1: Waste Minimisation – Source Reduction
- *BEDP Environment Design Guide:* DES 31: Design for Disassembly – Themes and Principles
- *BEDP Environment Design Guide:* PRO 22: How to Approach Material Selection for Waste Minimisation

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*The design and construction fields have a central role to play in moving toward a 'zero waste' economy. Total resource consumption, both upstream and downstream from development, could be greatly reduced through ecological design. This will however require a paradigm shift to a more whole systems understanding of waste - as distinguished from what we could term 'marginal analysis'. This paper introduces the idea of 'ecological waste', which accounts for the loss of ecosystems in assessing development. Ecological Waste analysis would consider the time and cost of replacing a living forest ecosystem and not just the biomass or 'resource'. This is intended to move the goal post toward the aim of eliminating 'designed waste', or the duplication, disposability, planned obsolescence and wasteful end purposes to which a large portion of resources are sometimes directed through design. For the purposes of this paper, sustainability is understood in its strongest sense: as expanding future options. It is recommended that note Gen 4: Positive Development is read as a preface to this paper.*[1]

**Keywords**

*designed waste, eco-innovation, ecological waste, eco-retrofitting, embodied waste, industrial ecology, waste*

## 1.0 Introduction

The waste and toxins created by construction and demolition are major contributors to total resource flows, pollution, habitat destruction and other environmental problems. Construction, renovation and demolition waste can be up to 80 per cent of land fill by weight, and about 44 per cent of waste to landfill by volume, some of it leaching toxic chemicals. Further, 50 per cent of packaging waste has been attributed to construction (Roodman & Lenssen, 1998). Waste costs money. The CSIRO estimates that efficiencies in the construction industry could create 3 per cent growth in Australia's GDP, along with a 10 per cent reduction in construction costs. Moreover while construction represents only +/-10 per cent of GDP, design largely determines the amount of *upstream* resource consumption and emissions in mining, forestry, transport and manufacturing. For instance, only 5 to 15 per cent of a tree ends up in wood products, with the conversion of logs to structural timber being +/-30 per cent. This means the specification of more efficient products like radial sawn timbers can generate compound savings upstream. The selection and design of materials can generate far more waste or economies than construction and demolition waste figures suggest, as these indicate only downstream waste. Moreover, these figures do not reflect how the design of environments and artefacts can also lock society into patterns of consumption *downstream* that perpetuate waste for decades. For example, poor design can require expensive maintenance, or encourage suburban sprawl. While waste has generally been regarded as a problem that emerges at the end of the pipe, most waste is 'designed in' long before products reach the construction site or building user. Arguably then, waste is mostly a function of design.

## 2.0 Doesn't waste depend more on behaviour than systems design?

There is nothing inevitable about waste. If it can be used as a resource for productive purposes, it is no longer waste. As many environmentalists have noted, there is no waste in nature, because 'waste = food'. From a biological perspective, humans do not produce more waste (poo) than other animals (and microbes could easily process this). Waste is instead produced by the *systems* that humans design, especially industrialised, fossil-fuel driven construction, manufacturing, transport and agriculture.

The built environment uses 3 billion tons per annum or over 40 per cent of materials world-wide (Roodman and Lenssen, 1995). To get an idea of the scale of waste involved, the UK construction industry consumes more than 400 million tonnes of materials and generates over 100 million tonnes of waste; around 30 million tonnes each year ends up as construction waste going straight to landfill each year (Building Industry News, 2006). Construction and demolition waste in the USA has been estimated at over twice that amount (Yost, 1999). If we are serious about sustainability we need to move beyond 'reduce, reuse and recycle' to a major 'rethink' of the end products of design (Hill, 2002; Wann, 1996). Our design methods, concepts and criteria need to catch up with the growing perception that all waste is harmful, not just the poisons like mercury and dioxins that are accumulating in the food chain, the environment and human body (McDonough and Braungart, 2002). Carbon dioxide for example, is a naturally occurring compound, but in the quantities that are being released it can alter our climate, sea levels, biodiversity and therefore wreak havoc on the economy (Tibbs, 2002; Stern Review, 2006). A zero waste economy will require radically different kinds of building prototypes and urban design principles.

[1] Versions of this material have been presented in the author's course notes and the concepts are explained in more detail in *Positive Development: from Vicious Circles to Virtuous Cycles* (in press).

## 3.0 Aren't there zero waste programs established to address these issues?

There are growing numbers of government jurisdictions that have 'zero waste' policies. Canberra was reputedly the first city to do so, but quietly dropped this goal. New Zealand as a nation now has a zero waste policy.

However when governments talk about zero waste they just mean no waste to landfill. Landfill represents a small fraction, about 6 per cent, of materials used in resource extraction and production that reach the consumer. Most of this is disposed of within a few months after purchase (Hawken, 1993). While 'true' zero waste may be theoretically impossible then, we are closer to 100 per cent waste than 0 per cent waste.

The rubbery use of the term 'zero waste' also reinforces the concept of waste as something that only occurs during production or after a product is purchased. Therefore waste is regarded as a consumption or consumer issue alone rather than a design problem. While consumption and design issues are inseparable, the focus on behaviour implies that society has to change behaviour first. This provides a good excuse for buck-passing by industry and inaction by regulators.

Consumers do not design the systems that result in waste, toxins and inequity. They can opt to choose fewer possessions, boycott specific products, or even have fewer children, but they cannot 'choose' products that have not yet been designed. In fact they have little say over what is on the shelf, how it got there, or what fashions will come down the pipeline next year. After all, consumers demand services, not waste. Fortunately the design professions are in a privileged position to create meaningful consumer choices. We may not be able to control how people use buildings or products, but we can design them so that conservation comes naturally.

## 4.0 Does this mean that recycling approaches are a waste of time?

Not at all. Although post-consumer waste recycling is an 'end-of-pipe' approach, its economic value should not be underestimated. For example, the Californian recycling and waste management industry accounts for 85,000 jobs, generates $4 billion in salaries and sales, and produces $10 billion worth of goods and services annually. In one year the industry saves enough energy to power 1.4 million Californian homes, reduces water pollution by 27,047 tons, saves 14 million trees, reduces air pollution by 165 142 tons, and reduces the GHG emissions equivalent to removing 3.8 million cars from the road (IWMB, 2005). In the built environment the opportunities for savings are also mind-boggling. The savings from recycling creates jobs and profits, and saves money and resources, while reducing public hazards and business risks (IPPR, 2006). Many waste audit tools, waste training programs, model waste reduction contracts and waste management plans, guidelines and strategies are now available to aid councils, designers and builders in generating efficiencies during construction (Bell, 2003; Forsythe and Marsden, 2004; Nolan, 2004; Graham 2002). Nonetheless, recycling programs address only post-consumer waste, a tiny fraction of the waste entailed in materials extraction and processing products.

'Cleaner production' and 'eco-efficiency' processes aim only to reduce toxins and not net resource consumption (Schmidheiny, 1992; WBCSD, 1997). Therefore these processes can only slow the rate of toxins accumulating in the environment. They are essentially process improvements to a non-sustainable development prototype. The future success of recycling will depend upon front-of-pipe strategies such as financing, product design, collection and processing infrastructure and end-markets. Simultaneously we could be closing loops in the construction industry by ensuring construction by-products are converted to resources and not waste. More importantly we need to develop building prototypes that use far less materials and energy in relation to the functions and services that they provide.

## 5.0 Why aren't existing construction waste management practices adequate?

Most waste minimisation strategies in construction are about process improvements to existing practices. While these are essential they can stimulate more compliance activity than design thinking. Process-oriented approaches tend to encourage 'ticking the boxes' instead of systems transformation through design. Take for example the experience of an environmental manager at a large university. His curiosity was piqued by the amount of waste that was leaving a building renovation site on campus, given that he knew the Council had approved their waste management plan. When he checked with the Council, their 'plan' was to *not* recycle glass, brick, aluminium, or for that matter, anything else. The builders were in total compliance with the plan.

Design thinking as opposed to process-oriented strategies is more likely to assist in making the quantum leaps required. Some well-known **eco-design** strategies include design for disassembly, environment, maintenance and adaptability (Crowther, 2005; EA, 2001). Unfortunately, these are still under-utilised. There are also some institutional mechanisms that could help stimulate better design on the part of industry. For example, 'extended producer responsibility' laws are beginning to be enacted around the world (Thorpe et al, 2004). These laws require producers to take back products at the end of their useful life and recycle them. There is also the idea of 'precycling' (Greyson, 2007). In this model premiums would be paid by significant producers according to the risk that their products end up as waste, with products that are more likely to become a new resource for other industries attracting a lower premium. Such systems design concepts are beginning to shift attention and funding from disposal to prevention.

## 6.0 How do system design approaches close loops and prevent disposal?

Some systems approaches like urban and industrial ecology, also called 'industrial symbiosis', aim to create efficiencies and synergies at a larger scale. **Industrial ecology** establishes links among different industries so that one industry's waste becomes another's resource. Industries can share utility infrastructure for energy production, water and wastewater treatment. Interestingly industrial ecology evolved without government initiatives or incentives because it made good business sense. It is now being picked up by major industries with government support in Australia and around the world (see Centre of Excellence in Cleaner Production at Curtin University of Technology: http://www.c4cs.curtin.edu.au, and Centre for Sustainable Resource Processing: http://www.csrp.com.au).

The Kwinana Industrial area in WA has established industrial symbiosis projects among heavy minerals processing and chemical industries (Bossilkov, van Beers and van Berkel, 2005). Another industrial symbiosis project in Wagga Wagga, NSW integrates secondary industries to capitalize on recycling opportunities including co-generation (recycled heat), water recycling, nutrient capture, and mining of valuable trace minerals, such as potassium from wool scours using natural bioconversion systems. The resulting clean water and organic fertiliser is being utilised on an adjacent farm. Thus the conglomeration of manufacturing industries are remediation the landscape, increasing profits to participants, and closing loops between the agriculture and manufacturing sectors. However industrial ecology does not reduce demand on living environments for raw materials in the first place. Imagine the environmental and economic costs we could avoid by removing waste from the whole supply chain through design, not just during processing and after use.

## 7.0 Does the construction industry use principles of industrial ecology?

We are a long way from construction ecology (Kibert, 2002). Instead waste minimisation strategies in the building sector aim to reduce or recycle the waste caused by conventional design. The main activities where resource efficiencies and recycling are currently practiced are:

- construction: modular and prefabricated systems, dimensions for standard material sizes, more detailed construction documentation, and specifying recycled materials
- demolition: design for deconstruction, reuse and retrofitting
- operation: design for maintenance and renovation, design for adaptability

Our building science tools enable us to substitute various existing industrial materials and technologies, but this generally has only marginal reductions in impacts. Closing loops, increasing resource efficiency or reusing waste generated by conventional design does not in itself reduce the ecological impacts upstream caused by mining, agriculture or forestry. Processes like geo-sequestration and incineration only slow the accumulation of impacts and disruption of habitats. They may be important in a mix of pragmatic steps, but, they only deal with part of the emissions or solid wastes after they are produced. Furthermore, every time something is recycled there is a loss of material and energy. What is missing from the suite of responsible design principles and practices is design that addresses the pre-construction phase. We could design buildings that use far less materials and energy sourced in ways that are far less damaging to habitats, and serve more functions to begin with. Imagine if we designed buildings that added value to the ecology and society rather than just reduced waste. Sustainable design will need to do more than reduce *pressure* on the environment from resource flows. It must also increase the health and resilience of the ecological base (see note *Gen 4: Positive Development*). Among other things, this entails design that uses passive solar systems and generates positive offsite social and ecological impacts. Both eco-efficiency and eco-logical design are needed.

## 8.0 What is the difference between eco-efficient and eco-logical?

Eco-efficient design and production processes can reduce resource consumption per unit of material or per product (Graham, 2004). Eco-efficiency reduces resource use and waste per unit of output, not total consumption. Resource-flows are continuing to increase despite the impressive efficiency gains made in recent years (Hawken, Lovins and Lovins, 1999; Weizsacker, Lovins and Lovins, 1977; Hargroves and Smith, 2005). We should remember that industries do not increase efficiencies or reduce impacts in order to sell fewer products. The efficiencies might be either lower prices to capture more of the market or, conversely, increased profit margins, but this does not reduce the increasing number of unnecessary or luxury items in the marketplace.

Shops are full of things we do not really need (Davidson, 2002). For example, there was no demand for electronic pets until they were designed and marketed. Designers therefore need to think eco-logically and consider the waste embodied in product *purposes* and building *prototypes* themselves. For example designers often:

- design more efficient lawn mowers, rather than plant native grasses or lawn covers that would eliminate mowing
- design more efficient kitchen appliances, yet foster demand for large, single-purpose, material-intensive kitchens, used largely for ordering in pizzas or microwaving processed food
- create demand for air conditioners by designing spaces that overheat, or under-designing for

passive solar cooling capability

- create better paints that emit less VOCs and other toxins, but do not reduce the use of paint, often using paint where it is not necessary.

As designers we need to make quantum leaps in our approach to design, not just our approach to resource use. A three-pronged approach to designing waste out of the system would help bring appreciation of the 'opportunity cost' of poor design.

**Step 1:** Think seriously about 'designed waste', which is the relationship between waste and design.

**Step 2:** Develop new concepts like ecological waste that take into account the living dimension, not just inputs and outputs of resources.

**Step 3:** Assess and prioritise innovations and investments in terms of their potential to improve ecosystem health, not just reduce negative impacts.

## 9.0 What is meant by the first step, awareness of 'designed waste'?

As a society we need to appreciate the role of design in generating excessive waste and toxins. Waste is currently designed into our industrial and construction systems. 'Designed waste' is therefore used here to capture the notion of the duplication, disposability, planned obsolescence and wasteful end purposes to which resources are put through poor design. To summarise:

- products are designed for wasteful purposes or redundancy
- a small fraction of materials used in production ends up in products
- a small fraction of waste is diverted from landfill
- many products are designed for planned obsolescence and/or disposal
- much of what is bought is surplus to need, including extra cars and homes
- reused materials and goods are mostly 'down-cycled' to lower uses
- packaging can be resource intensive and require us to buy ten bolts when we need one
- a small fraction of waste is diverted from landfill, and even less is recycled
- many products combine materials which then cannot be recycled economically
- the means of survival such as natural capital stocks and ecosystem services are being laid to waste

Avoiding designed waste requires systems design thinking. For example, when consumers save resources and therefore money, we sometimes see a 'rebound effect'. This is where consumers spend the extra money on carbon rich or conspicuous consumption elsewhere (Harrison et al, 2002). The rebound effect can probably only be addressed by designing built environments that create a rich range of low-impact choices. After all, environmental solutions that rely on altruistic and responsible behaviour can never be foolproof. Design approaches that make resource conservation convenient and comfortable, and make responsible living 'cool' are therefore more likely succeed, like one sportswear firm's new 'compostable' shoes.

Designers can also capitalise on the potential of design to use waste from surrounding development and generate positive offsite impacts. Storm water runoff and organic waste from adjacent land uses can be captured and used locally to support 'agri-tecture' rather than piped or trucked away. For example, Melbourne's CH2 office building 'mines' water from public sewers.

## 10.0 What does the second step 'ecological waste analysis' entail?

Step 2 suggests we need to eliminate designed waste through better planning, design and decision making. We need new concepts for understanding, assessing and measuring waste. As a society we undervalue the biodiversity, ecosystems and means of survival that nature provides, let alone nature's tangible 'products' like energy, water, space and materials. Since our society does not value nature as a living ecosystem(s), we do not consider waste at the ecological level. Instead of supporting ecosystems, biodiversity and habitats, our strategies aim to reduce pressure on the environment 'as a resource' through more efficient use. So when we assess environmental impacts it is only in terms of inputs of raw materials and outputs of pollution. *Resource* efficiency is essential but not sufficient. We also need to design for *ecological* health and resilience. In life-cycle assessments of course, we add in numbers based on subjective values of experts to represent negative impacts at the source of resource extraction and/or its disposal in nature. However we seldom, if ever, take into account the time and space needed to restore the ecology. That is, we do not see the forest for the trees.

We can identify three different levels of thinking about designed waste in the built environment: timber, trees and forests are used to illustrate these levels:

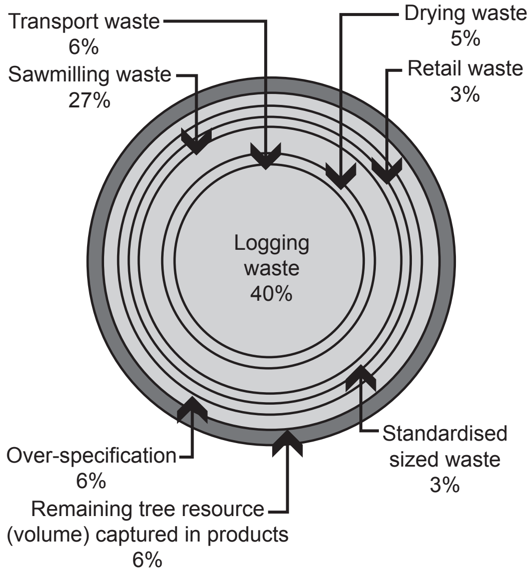
1. '**Material flows**' analysis and/or life cycle analysis, applied to waste, would aim to reduce the amount of timber going to landfill or discarded prematurely. This best practice approach would consider cumulative waste and efficiency in extraction, production, delivery and construction, and/or the longevity of the product. However, it would not seek the highest ecological use of the timber or weigh in its replacement cost or regeneration time (see Figure 1).
2. '**Embodied Waste**' would include embodied materials as well as energy and water. Those who take this view of waste would aim beyond reducing cumulative waste, increasing efficiency, or increasing the amount of the tree embodied in final products. Metaphorically embodied waste is the 'hole in the donut'. One can reduce the size of the hole, or turn the 'donut holes' into positives and sell them. That is, we can have our donut

and eat it too. The assessment would consider the lifespan of the resource, and not just the product: the time it takes to replace the trees. In the case of timber, embodied waste would take into account:

- timber volume
- percentage of the forest captured in permanent products
- rotation period or replacement time of the trees
- public costs entailed in forest management and regrowth
- lifespan of the products
- the end use of the product

While we know the preservation and enhancement of the ecological base is essential to achieve sustainability, we largely ignore it because we do not have the data or processing tools to measure it. Instead of trying to model nature – which is impossible – we can use nature as a model. This is relatively easy (Benyus 1996, Beattie and Ehrlich, 2004). But we should also try to ensure the product purpose or end use is also ecologically responsible. We do not need to wait for data and computer programs to do this. Embodied waste is only a portion of the ecological waste, as it only looks at the trees as a resource. Even when we add up the material flows of the tree 'as timber' along the various stages from extraction to construction and eventual demolition, this approach does not capture the replacement time, and long-term public costs of ecological sacrifices.

3. '**Ecological waste**' would count the costs of restoring the whole ecosystem. It would consider the resource base as a *living* system and would notionally or quantitatively measure the effects on the life support system, future social options, and the equitable distribution of the means of survival. That is, it would 'weigh in' the replacement cost, time and value of the forest as an ecosystem, not just the trees or timber resource in them (see Figure 2).




Cumulative waste through the supply chain does not consider the life span of the timber product or the replacement cost and time to replace the tree, let alone to restore the ecology.

Percentages of waste are highly variable depending on forest type and forest practices. However, cumulative waste can be 94% of the total tree. That is transport wasting 6% of what's left after logging; and logging wasting 40% of what was the whole tree, etc.

**Figure 1. Material flows of trees in timber production ('donut model')**
(quantities from Jehne, 1996)

## 11.0 Don't assessment tools consider time, cost and value already?

Generally our assessment tools are designed to predict the future damage of our plans and designs. For this reason, we often largely ignore or undervalue past and ongoing damage caused by the existing built environment. We generally only count the additional costs from this point on, not the cumulative ongoing costs of existing development systems. Development assessment and even sustainability assessment processes have been highly selective. They seldom if ever weigh in the costs of inaction and opportunity costs of poor design.

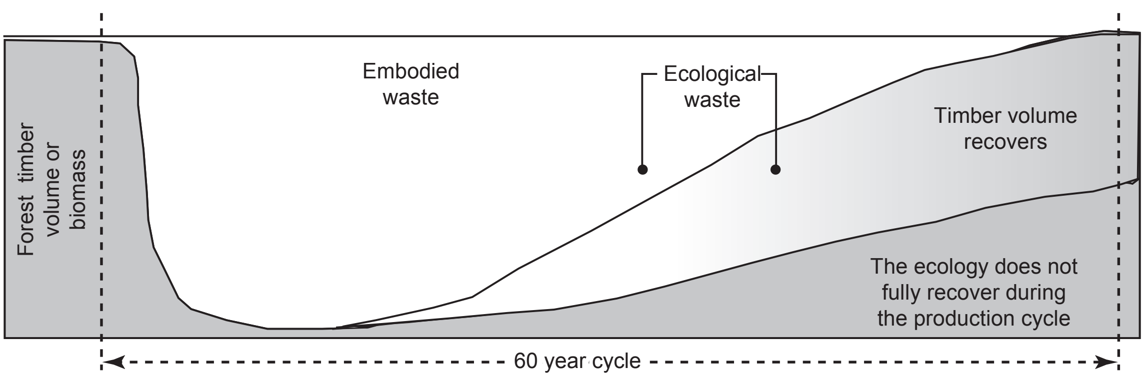



**Figure 2. Ecological waste of forests in timber production**

One of the consequences of taking a snap shot in time is a bias against the eco-retrofitting of existing cities. For example, councils usually ignore the waste of energy that is being lost due to allowing existing development to remain as is. Councils also seldom consider the environmental costs of demolition, as greenfield development, or 'a clean slate' is accepted as the baseline. Since project assessment and approval systems undervalue or ignore the ecological waste entailed in demolition and new construction, these tools favour new development.

Selective measurements of waste distract us from addressing the following fundamental truths:

- costs and impacts of existing development are non-sustainable
- resources required to replace existing development with 'green' buildings are too great

Even if we could harvest enough materials, water and energy sustainably to replace the existing building stock with new green buildings, we would only be reducing *relative* embodied and operating energy. Resource flows in new construction, and their ongoing costs, would leave us further from Sustainability than we are now. So we need to invest more creativity and imagination into eco-retrofitting to generate air, water, soil and biota that are healthier *after* construction than *before*. How to measure positive impacts is discussed in *Gen 4: Positive Development*.

## 12.0 Wouldn't reducing ecological waste hurt economic progress?

Not if we define economic progress in terms of human development and life quality, as many ecological economists have argued (Hamilton, 1997; Eckersley, 2002). Assessment systems only provide information and guidance. They do not make the decisions or generate design solutions. Decision makers and the general public may continue to choose designed waste over eco-logical design, deliberately or unthinkingly. While 'design' creates something that does not yet exist, assessing and 'choosing' among options is a relative matter. For example, selective forestry or plantations grown on degraded land for timber products might generate less ecological waste than clear-felling and mining native forests for woodchips.

Decision makers can ignore such critical sustainability issues like time, space, living ecosystems and the wealth transfers entailed in allocating land and resources to development. Nonetheless the public has a 'right to know' what is happening. Basic democratic rights are inextricably linked with the control and access to the means of survival, much of which is determined by land use and development control decisions. For example, an ecological waste analysis on whether to build a nuclear power plant would put a value on time, space, and ecosystem functioning – along with the other impacts and issues like reliability of uranium supplies, nuclear proliferation, etc.

An ecological waste analysis for a nuclear power plant would also include:

- The costs of storing spent fuel rods for thousands of years. One could include an 'eco-rate' to compensate for the greater value the environment will have in the future, in lieu of 'discounting' future costs to present values
- The land area or space that uranium mining and waste storage would alienate from other purposes over thousands of years
- The time required for the ecology to restore itself
- The effective commissioned life span before the plant becomes a contaminated liability (only about 50 years). The costs of decommissioning nuclear power plants has generally been left to the taxpayer
- The purposes to which the uranium will be put as well as the alternative means of achieving these end uses.

## 13.0 So how would we assess innovations and prioritise investments?

Currently we add up the costs and benefits of environmental change from this point on. These are used as a basis for approving development proposals when put on the table by willing investors. Remarkably, the benefits need only be deemed to outweigh the costs. The project need not contribute positively to sustainability objectives; it only needs to be less unsustainable than conventional buildings. In theory the market should be able to close loops, as eco-efficiency improvements to existing processes and products are inherently cost effective on a level playing field. In fact, green building retrofits have been shown to pay for themselves (Romm, 1999; Nevin & Watson, 1998). However, our environment is being shaped to fit an economic model and decision process that treats the environment as a resource, not a living life support system.

We should instead be allocating public investment to stimulating eco-innovations that improve human and environmental health and whole systems efficiency. This can be achieved by utilising natural systems to replace resource-intensive machines and products. We could reverse the process of market driven innovation, and instead determine positive opportunities for innovators and investors to address. Rather than picking winners and losers, planners could identify problems and waste in the existing environment that developers can address through Positive Development (development that leaves society and the ecology better off after development than before). The proposed hierarchy of eco-innovations (Appendix A) would encourage innovation that adds ecological, social and economic value to current and future development. It would provide criteria for public investment, grants and award decisions. Such a hierarchy might also encourage direct government investment in solutions rather than complex, expensive arrays of indirect incentives with unpredictable outcomes.

## 14.0 Conclusion

There is no human need (material or non-material) that requires ecological waste. Greening the old prototype or constructing less wastefully is no longer enough. Each change to the environment affects future life choices and the health and viability of the ecological support system. We have traditionally made planning and design decisions according to what is the least bad land use option, or the best design alternative for which there are current investors. Then we implement complex regulations, incentives and tools to encourage them to reduce waste and mitigate negative impacts at the margins.

The time has come to consider the opportunity cost of built environment design. Greening the old prototype, or constructing it less wastefully, is no longer enough. We have the capacity to create adaptable, reversible and 'compostable' cities and buildings that provide infrastructure for the natural life support system, provide responsible choices and expand future social options. The concepts of designed waste, ecological waste, and hierarchy of eco-innovations will help us in our shift toward more eco-logical forms of planning and design.

## Appendix A: Hierarchy of eco-innovation (from lowest priority to highest)

The following are abbreviated descriptions of different levels of design:

1. New designs, products or production systems that increase resource flows, but at less negative impact per unit than the norm, are relatively low priority as they only reduce the relative impacts of future actions. The market should manage this on its own as efficiency is good business.
2. Innovations that reduce the impacts of waste from ongoing processes or activities, through reuse, recycling or re-assembly, often involve some waste and a reduction of use value or 'down-cycling'. Recycling programs should generally be self-sufficient and only require initial support.
3. Innovations that reduce the impacts of past development (toxins or waste already in the environment) although adding economic value are called 'up-cycling'. Some up-cycling can involve an increase in conspicuous consumption and hence contribute to unnecessary resource flows.
4. Up-cycling refers to innovations where waste is 'designed out' of an existing, ongoing or future system entirely while adding economic value (what McDonough and Braungart call 'no loop' systems). This could still create unnecessary products or have a rebound effect.
5. Eco-Cycling is up-cycling that contributes to human and ecological health (i.e. net positive) and does not unnecessarily increase consumption. However, this may still not necessarily increase access to the means of survival and resource security – of the public estate.
6. Innovations at the net positive level improve whole systems health both offsite and onsite, provide useful public goods and services, and increase usable space and accessibility – in addition to human and ecological health benefits. That is, they increase both the public estate and ecological base. They can be at the building or system level:
   - Net Positive Development reverses existing impacts and increases the ecological base (and human and ecosystem health) and public estate beyond pre-development site conditions.
   - Net Positive Systems innovations create levers for biophysical improvements and social transformation at a whole region or global scale (e.g. converting cities from fossil to solar).

## Appendix B: Glossary of terms used in a special way

**Designed Waste** is the redundancy, disposability, planned obsolescence and wasteful end purposes to which resources are put through design: for example, creating a need for lawn mowers, rather than planting native grasses or lawn covers to eliminate mowing.

**Eco-Innovation** is an institutional or technological design that improves human and environmental health, wellbeing and equity while reducing resource consumption (i.e. whole systems efficiency), by utilising natural systems that replace 'unnecessary' machines or industrial products.

**Ecological Waste** is the loss of ecosystems and encompasses the time and cost of replacing them; that is, the whole forest ecosystem, and not just the biomass. Ecological waste (a negative measure) is the converse of the ecological space (a positive measure).

**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' or net positive improvements over existing conditions.

**Embodied Waste** refers to the total 'accumulated' waste occurring at each stage of the whole production/consumption process over the product's life span (e.g. the percentage of the tree not captured in products). It includes embodied energy, water, materials and other waste.

**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'. Those services not under private control represent the 'public estate'.

## Appendix C: Terms used in conventional ways

**Design for adaptability** has been developed to ensure access and use of buildings and landscapes by disabled and elderly (becoming even more important as the population ages). Construction details have been developed to enable retrofitting to accommodate such people.

**Design for disassembly** ensures that components of a product are easily separated for purposes of recycling to enable producers to 'take back' products more cost effectively after use. The tyre exemplifies a product that is difficult to deconstruct due to the mix of materials.

**Design for environment** minimises environmental impacts over the product life-cycle from resource extraction, manufacture, distribution, use or operation and recycling: the minimisation of resource use and waste for maximum output of industrial processes.

**Discounting** is where economists reduce future to present values to account for inflation and the fact theory that people are generally willing to pay more today to have something now than in the future. We do not take into account the increasing scarcity of natural resources and amenity.

**Eco-efficiency** is the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle (World Business Council for Sustainable Development).

**End of pipe design** or technologies are those that filter or disperse pollution, instead of changing the materials, processes, fuels or other elements of design that cause the pollution in the first place, or closing loops so that waste is at least used as a resource.

**Industrial ecology** is where industries work together to utilise by-products from another industry. Industries can share utility infrastructure for energy production, water and wastewater treatment.

**Material flows analysis** applies the concept of 'metabolism' as a model for analysing material flows through urban and industrial systems. In biology, metabolism refers to the chemical reactions by which an organism or ecosystem interacts with its environment.

**Rebound effect** is where a more energy-efficient product reduces the costs of production or operation, but leads to an increased use of that product (such as efficient cars that are driven more miles) or the money saved is spent on other products or services with greater impacts.

**Zero waste** should refer to where all waste generated in the supply chain is prevented or reused. However 'zero waste' is usually used to mean 'zero waste to landfill'. Less than 10 per cent of materials consumed in production are captured in a product, the remaining 90 per cent being either recycled or waste (Hawken, 1993).

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