ENVIRONMENT DESIGN GUIDE

BEYOND CARBON NEUTRALITY: STRATEGIES FOR REDUCTIVE AND RESTORATIVE SUSTAINABILITY

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Summary of Actions Towards Sustainable Outcomes

Environmental Issues/Impacts

- The use of energy-intensive non-renewable building materials has grown rapidly for over half a century. Addressing the challenge of climate change requires that the use of less carbon-intensive materials.

Learnings

- In the context of the built environment, sustainability can be viewed in terms of reducing ecological impacts (reductive sustainability) and repairing previous environmental damage (restorative sustainability).
- Both reductive and restorative measures will be necessary if we are to prevent dangerous climate change and achieve a sustainable built environment.

Related EDG Papers

- GEN 4, August 2007, 'Positive Development: Designing for Net Positive Impacts'
- GEN 40, August 2001, 'Implementing Ecologically Sustainable Development'
- DES 31, August 2005, 'Design for Disassembly – Themes and Principles'
- NOT 7, May 2005, 'Measuring Progress towards Sustainability – Bellagio Principles'
- PRO 7, May 2007, 'The Environmental Impact of Building Materials'

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This paper looks at the role of the built environment in our un-sustainability and explores the full spectrum of strategies and solutions as to how buildings might become a pathway towards a sustainable future, using carbon as a proxy. In addition to traditional notions of reductive sustainability, it explores restorative strategies and advocates a '5Rs' solution: 'Reduce, Re-use, Recycle, Repair and Restore'.

Keywords:
materials, carbon metrics, LCA, restorative sustainability, climate change mitigation

The Gold Coast, South-East Queensland (© iStockphoto/Jenny Bonner)

1. INTRODUCTION

In the first decade of the 21st Century, domestic climate change policies have focused on reducing the carbon emissions generated by fossil fuel-based energy systems. This is an important goal, but equally important is the need to address the significant amount of carbon emissions embodied in buildings, infrastructure and lifestyles.

Embodied energy and carbon in the built environment will become a key challenge for policymakers as an increasing proportion of the global population moves into cities. While it takes massive amounts of energy to run cities, they also require vast amounts of energy to build, fit out, provide infrastructure for, resource, clean, maintain, demolish and renew. Whether it be building or refurbishing homes, commercial or industrial buildings, there is a need to modify these practices to reduce future ecological impact and repair historical impacts. To an extent, environmental management has tended to focus on reducing impacts, leaving restoration in the margins and to nature.

The two approaches can be categorised as 'reductive' and 'restorative' sustainability. Reductive sustainability includes initiatives that incorporate past waste into new products or use resources more efficiently. These have a critically important role in promoting sustainability, up to a point. But the question remains, how can we create a net positive impact to redress past impacts if we

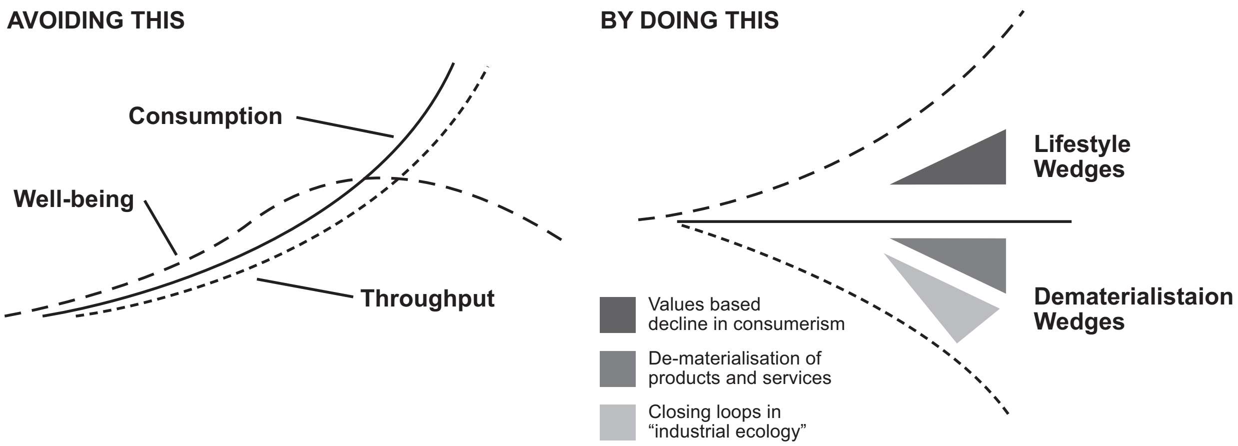

Figure 1: Vision of unsustainable systems (left) and three proposed interventions necessary for sustainability (adapted from Heij 2002)

only ever reduce a future negative impact? This is where restorative sustainability, with its focus on enhancing nature, can begin to pro-actively support nature by creating initiatives that have a net positive impact.

This paper will outline the major issues and actions within cities. It will define, compare and contrast reductive and restorative sustainability. It will look at the important reductive sustainability actions that can be implemented to reduce future impacts, as well as identify actions that have a restorative function.

2. DEFINING SUSTAINABILITY

There are numerous definitions of environmental sustainability. Those presented by the Brundtland Commission and Australia's *National Strategy for Ecologically Sustainable Development* focus on mitigating impacts, maintaining intergenerational equity and working with the 'precautionary principle' (Brundtland 1987). These are very broad overarching principles that do not really help practitioners identify and implement optimal strategies. In fact, we do not really have a clear idea what a truly sustainable city actually looks like or how it can operate, given the extent of existing development infrastructure and systems.

According to Heijj (2002), there are three 'sustainability wedge' strategies required to deliver sustainability (Figure 1). These strategies provide some general guidance on the directions we need to move to redress unsustainable practices.

The Swedish sustainability think tank the Natural Step Institute has developed its own system conditions for sustainability. The Natural Step's 'Four System Conditions for Sustainability' adds detail to the CSIRO definition:

1. Substances from the lithosphere (within the earth) must not systematically increase in the ecosphere
2. Substances produced by society must not systematically increase in the ecosphere
3. The physical basis for the productivity and diversity of nature must not be systematically deteriorated
4. There must be fair and efficient use of resources with respect to meeting human needs

(Natural Step n.d.)

According to the Natural Step, these system conditions must form the basis of assessment tools for products, services and strategies.

3. REDUCTIVE AND RESTORATIVE SUSTAINABILITY

Heij (2002) argues that for societies to begin the major process of holistically moving toward real sustainability, they must make progress in the following areas:

1. A values-based decline in consumerism
2. A dematerialisation of product and services
3. Closing the loop in industrial ecology

These three points represent reductive sustainability. That is, reducing future impacts. This is exhibited by the now common 'Three Rs' catch phrase: reduce, re-use, and recycle. Allied to these are a range of variant strategies promoted by such books as Weizsäcker et. al., *Factor Four – Doing More with Less*, William McDonough and Michael Braungart, *Cradle-to-Cradle*, Paul Hawkins, *Natural Capitalism* and Janine Benyus, *Biomimicry*.

It is assumed that if we reduce our impacts, nature can self-repair and recover over time. While the reductive sustainability discussed in the above works include important initiatives such as incorporating past waste into new products or doing twice as much with half as much (Factor Four), they can only promote sustainability up to a point. This is where restorative sustainability becomes a useful concept.

So what is restorative sustainability and what constitutes a restorative solution?

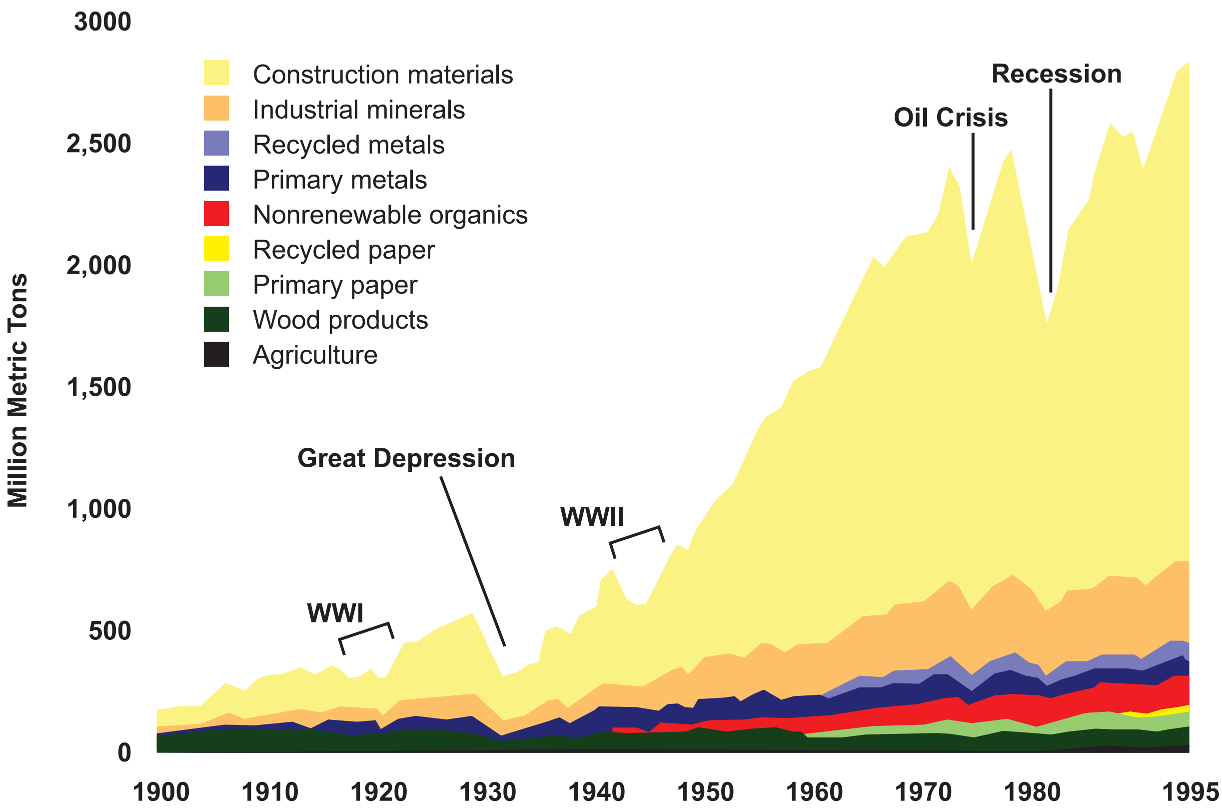

Figure 2: The growth in US materials consumption by sector 1900–1995 (Matos and Wagner 1998)

To be restorative, a strategy, process or product would meet all four of the Natural Step's System Conditions for Sustainability plus involve one or more of the following:

- Reduce substances produced by society from the ecosphere
- Repair and restore ecosystems and increase the diversity of nature
- Be long-lived, perpetual or self perpetuating
- Be non-maintenance or very low-maintenance

So far as outcomes are concerned, restorative sustainability creates net positive environmental and health outcomes, multiple ecological benefits, and other long-lasting positive effects.

If we reduce our demands on nature's systems and living resources, there is no doubt that regeneration will occur to some extent. However, the plain likelihood remains that we will be unable to create enough relaxation in the societal demands we place on natural capital to allow adequate natural recovery in currently highly stressed, damaged or destroyed ecosystems to ensure sustainability in the long term if we only ever reduce future negative impacts without redressing past impacts.

There is a dire need for built environment practitioners to adopt an 'enhancing nature' focus. This pro-active focus on supporting nature requires us to, where possible, create initiatives that have a net positive impact that put back more than they take out of our natural capital. Efforts to restore natural capital would therefore need to integrate methods, technologies and practices into all aspects of the built environment that repair and restore nature.

4. ENERGY USE IN OUR BUILDINGS

In 2007, the global building sector generated 8.2 gigatonnes of carbon emissions ($GtCO_2e$), 21 per cent of total emissions. The residential subsector consumes 76 per cent of global resource/energy/electricity supplies and 63 per cent of emissions, and the commercial subsector generates the balance (Vattenfall 2007). These figures only account for the recurrent operational impacts, and do not account for the embodied emissions of the sector.

A significant amount of energy is hidden and largely ignored. This is the embodied energy and carbon emissions contained within the materials used in buildings and their infrastructure. According to Roodman and Lensen, 1995:

> Buildings account for one sixth of the world's fresh water withdrawals, one quarter of its wood harvest, and two fifths of its material and energy flows… Building and construction activities worldwide consume three billion tons of raw materials each year, or 40 per cent of total global use.

The energy embodied within materials, products and technologies are a result of their raw materials procurement, manufacturing and packaging. This is a key factor in the carbon footprint of buildings, yet is largely overlooked in the macro studies of potential CO_2e savings. Growth in the construction materials sector between 1945 and 1995 has been astronomical (Figure 2). It is in the interests of policy makers and practitioners, therefore, to address the continued growth of energy-intensive building materials.

When we look at the relevant proportions of operational and embodied energy in the residential sector, as exemplified by the 30-year analysis of a typical household in Figure 3, and a 40-year analysis of a 40,000m² office building in Figure 4, the majority of energy is consumed in operational energy. (It should be noted that the percentage of impacts attributable to a building's initial embodied energy will of course vary depending on the building's lifetime.) However we also see a significant proportion of overall energy resulting from embodied energy, not just of the buildings themselves but of also of recurring consumption as part of the overall 'lifestyle' of the occupants.

In the residential sector this is seen as a personal or family lifestyle. In the commercial sector, the combined 'lifestyle' of companies results in that sector's second-highest embodied energy factor, being the churn of furniture, fittings and finishes due to short leases, corporate image and fashion design trends. What's more, the increase in construction materials consumed corresponds with a decline in the use of renewable sources of materials (which tend to be low embodied energy) (Figure 5).

5. IDENTIFYING IMPACTS AND ABATEMENT MEASURES

Much research has already been conducted which identifies existing impacts and abatement measures in terms of the carbon emissions generated from cities. Potential annual savings of 27.1 gigatonnes of carbon emissions ($GtCO_2$e) costing under €40/tonne (AUD$67/tonne) has been identified by Enkvist. Almost 14 per cent (3.8 $GtCO_2$e) of this potential abatement is in buildings alone (Enkvist 2007).

A similar study by the European energy company Vattenfall (2007) identified a total of 3.7 $GtCO_2$e of low-cost abatement options. This includes 3.0 $GtCO_2$e in the residential sector and 1.3 $GtCO_2$e in the commercial building sector globally. The combined savings in the residential and commercial sectors are capable of holding emissions growth for the construction sector to 26 per cent between 2002 and 2030. For example, heating and ventilation, building envelope improvements, water heating and air conditioning provide the large abatement opportunities for both sectors and could contribute a total of 2.3 $GtCO_2$e reduced. In the residential building sector, improved lighting can potentially reduce emissions by a further 0.3 $GtCO_2$e, improved electrical appliances and reducing standby losses yields equivalent to an additional 1.1 $GtCO_2$e of abatement.

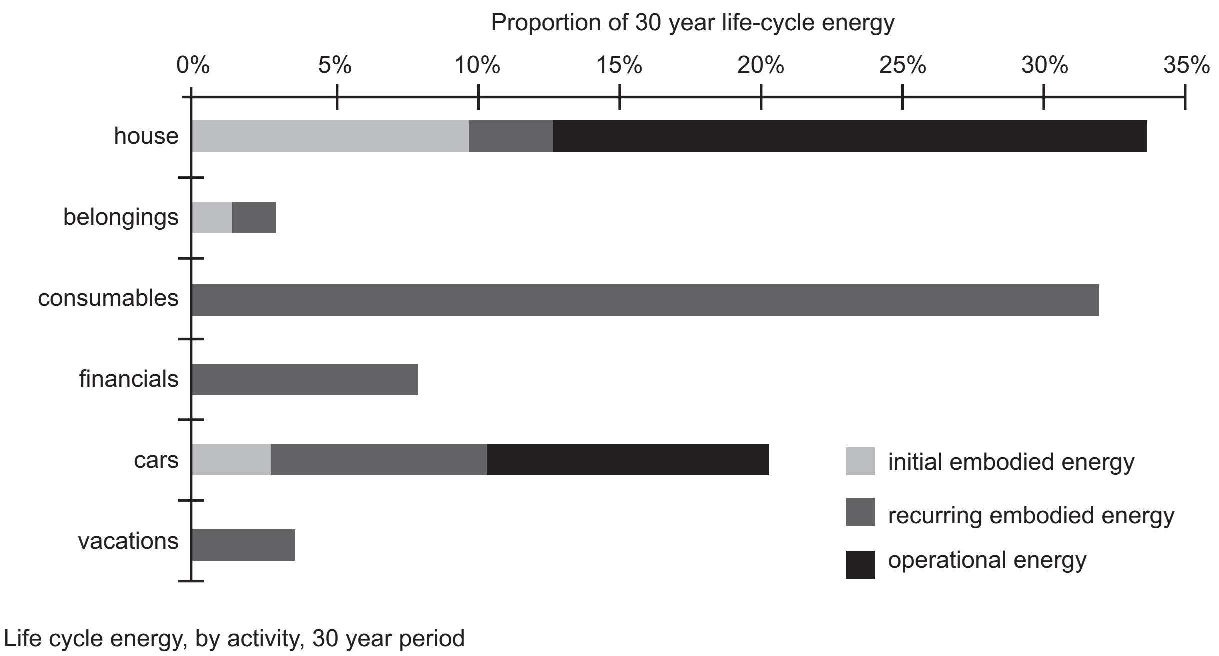

Figure 3: The proportion of energy attributable to initial, recurring, and operational energy of residential households (Treloar et. al. 2000)

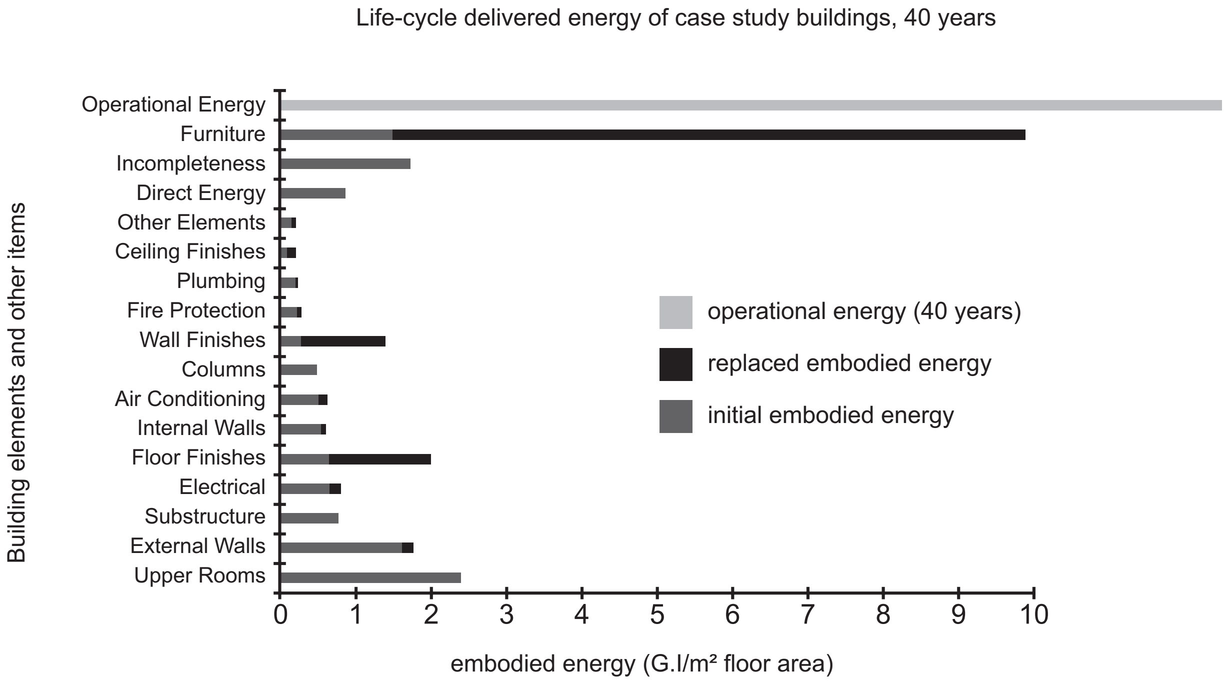

Figure 4: The proportion of energy attributable to initial, recurring, and operational energy of a 47,000m² commercial office building over 40 years (Treloar et. al. 1999)

6. REDUCTIVE SUSTAINABILITY: THE ROLE OF MATERIALS AND DESIGN

The global economy must reduce carbon emissions by 60 per cent by 2050 to limit global warming below the critical 2–2.5ºC threshold (Raupach 2007). The role of materials has a key role to play to reach this goal. But how can the potential for emissions reductions from buildings and their materials be realised?

There are number of key strategies where materials selection and the ways in which they are incorporated into buildings can provide benefits with little, and often no, cost – sometimes even with cost savings. This focus on reducing impacts by design, cleaner production strategies, materials selection and evaluation strategies represents a reductive approach to sustainability.

What follows is a list of reductive design strategies for practitioners to consider:

Materials choice

There is much to be gained from identifying the best of class, from an environmental perspective, within any materials category. There can be a substantial difference between the best and worst performers in some categories. An industry database of life-cycle assessed products and materials, such as ecospecifier.org, can help in this regard.

Industrial Ecology and 'Cradle to Cradle'

Since the early nineties, various authors including Frosch (1992), Allenby (1992) and Ayres (1994) have introduced the concept of industrial ecology, where technical cycles are designed to mimic natural organic cycles. The theory posits that, like natural systems, industrial development can produce no waste at all. McDonough and Baungart (2002) coined the terms 'waste equals food' and 'cradle to cradle' to describe how the carbon (and ecological) footprint of materials, products and technologies needs to be re-designed to ensure that the materials inherent in them and their production and manufacture systems will allow all elements or sub-components of any product on deconstruction, to fit within one (or possibly both) of these cyclic production/consumption/remanufacture/consumption systems.

Design for Disassembly (DfD)

Manufacturers and built environment professionals can design in ways that facilitate disassembly, or at the very least do not hinder it. This practice would be implemented by designers, engineers, specifiers,

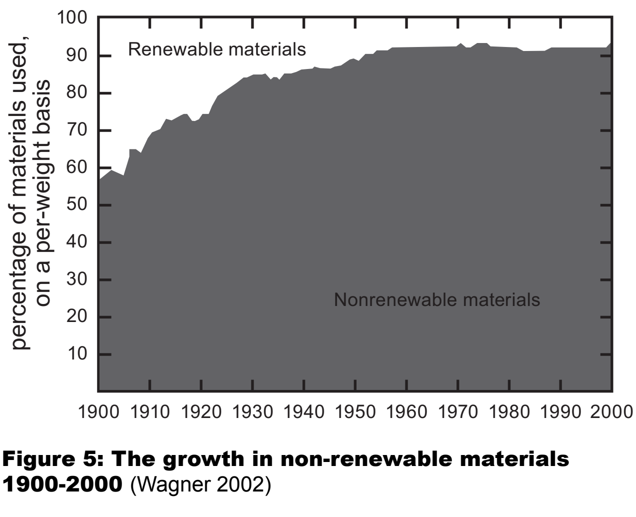

Figure 5: The growth in non-renewable materials 1900-2000 (Wagner 2002)

Western red cedar, a durable and renewable resource when sourced sustainably
(© iStockphoto/Ryerson Clark)

builders and developers. DfD practices create a resource that it is not lost and can enter the 'cradle to cradle' recycling loops that in theory do not need to be replaced with virgin resources at end of first or subsequent use.

Recycled Materials

Purchasing building materials that are easily recycled can contribute to reducing the future energy needed for disassembly and reuse. Purchasing products and materials that contain recycled content are also advantageous for reducing embodied energy.

Design for Climate (DfC)

Also known as 'passive solar' design, DfC means designing buildings and incorporating materials to maximise the use of heat sinks and sources for climate control and lighting. This is facilitated by the appropriate use of windows, shading, insulation, ventilation and thermal mass. DfC is the most powerful design strategy to minimise the operational carbon footprint of buildings.

Design for Durability

The single most important issue in life-cycle impacts of buildings and materials is durability, providing the carbon payback period is more or less short term. It is an unfortunate reality than many (not all) highly durable materials are high in embodied energy. For this carbon investment an avoided energy return needs to be calculated. What are the savings that accrue as a result of durability, avoided maintenance, or unnecessary replacement? Does this material/product create more carbon savings than the initial investment over a term of preferably less than 10 (in some cases up to 40) years?

Carbon Payback

The period it would take to amortise the difference between the lifetime carbon cost of one system against another, accounting for the differential length of replacement cycles vs. the added carbon cost of higher durability.

Biomimicry

In her 1997 book, *Biomimicry: Innovation Inspired by Nature*, Janine Benyus argues design practitioners can reduce ecological impacts by modelling their designs on nature. Key lessons that can be drawn from this approach relate to the ways in which products are evaluated and selected, and also how they integrate ecological cycles. Working with nature to restore function is implicit in the concepts promoted by biomimicry, however there is no explicit focus on restorative solutions.

Dematerialisation and Factor Four

In *Factor Four: Doubling Wealth, Halving Resource Use*, Weizsäcker, Lovins (1997) recommend 'doing twice as much with half as much' through a process of dematerialisation. Dematerialisation is simply about increasing the efficiency of materials. The approach enables technology and markets to drive efficiency. In the context of building design, the efficient use of resources is influenced by the structural design, detailing practices and the level of finish.

Renewable Inputs

Subject to the location and method that products are manufactured, transported and used, the use of renewably sourced products can have a major impact on reducing overall environmental and carbon impacts.

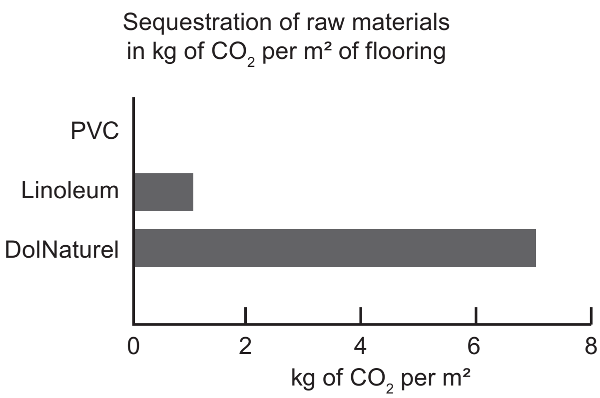

Figure 6: Showing the claimed carbon sink benefits of a natural rubber based flooring over other natural and synthetic floor coverings.
(Source: Dalsouple International)

The roof of the California Academy of Sciences in San Francisco (Image: Orana Sandri, 2009)

Some renewable materials are highly durable, e.g. western red cedar. However renewable materials can be sourced in ecologically unsustainable ways, so care must be taken in their purchase. Third-party sustainability accreditation helps buyers to ensure that the renewable resources they purchase have been sourced sustainably.

Identify Carbon Sinks

Some products that bind large amounts of carbon in the materials themselves during use are called carbon 'sinks'. Provided the materials are long lived, there are significant benefits in starting to increase the use of products that are high density carbon sinks. As shown in Figure 6, even among the renewable materials field there are claims of preferential carbon sink benefits beginning to emerge. How these products are dealt with at end-of-life then becomes doubly important if the embodied carbon is not to be released into the atmosphere.

Landfill Mining

Landfill sites can be used for extracting materials that would otherwise pollute environments, essentially a form of recycling. Landfill mining can also produce energy from methane capture.

7. RESTORATIVE SUSTAINABILITY: SOLUTIONS IN PRACTICE

The following initiatives represent a restorative approach to sustainability. They have a nature-enhancing focus that aims to repair past damage. You will notice that several of the restorative measures also produce reductive benefits.

Green Roofs and Earth Integrated Buildings

Green roofs and walls, and earth integrated and earth covered buildings, provide a diverse set of benefits that reduce ecological impacts. These include energy savings; carbon, pollution and nutrient sequestration; and reduced urban heat island impacts. But importantly, these built environments enhance nature through the provision of new environments for flora and fauna. Green roofs and walls can restore biodiversity through increasing soil organic matter and vegetation, and locally indigenous plants and animals (Baggs 2007).

As a word of caution, it is important to consider the whole-of-life-cycle greenhouse impacts of green roofs

Landfills can be used to produce energy and source materials (© iStockphoto/Roger Milley) and earth covered building. The deeper soil profiles associated with better energy returns tend to require more structural resources and hence higher greenhouse intensity due to higher embodied energy. Life-cycle analysis can ensure that green roofs are carbon positive.

Restitution of Indigenous Plant Associations and Ecological Values

While not relevant to every site, some sites (and rooftops) may be suitable for the re-establishing of areas of plantings using locally indigenous plants and soil profiles. While this not an inherently easy process, if enough patches of restored ecosystem were installed, they would be likely to provide biodiversity benefits by allowing and encouraging the repopulation of areas with indigenous native insects, birds and other animals.

Probiotic Water Treatments

Probiotic water treatment methods are non-toxic, biodegradable, and self perpetuating. They function by digesting solid waste to transforming effluent ponds into usable water. They are suitable for any organic waste removal and organic odour control and sanitation in industrial, commercial and residential applications. They contain beneficial bacteria to effectively reduce biological oxygen demand (BOD), ammonia, nitrates, nitrites and other pollutants including TSS (total suspended solids), E. coli and pathogens in sewage systems. The microorganisms continue to assist even out into the broader environment maintaining their beneficial conversion of nutrients and reduction of pathogens provided aerobic conditions exist.

Offsite Tree Planting

This strategy is being used widely as a carbon emissions offset tool already. The benefits that accrue will actually depend on a variety of issues such as the area being planted, the planting style (monoculture or diverse), forestry practices and adjoining ecosystem integrity. It is best if diverse communities are planted which adjoin high-quality forest with similar locally derived seedstock to allow more holistic re-colonisation of the ecosystem over time.

7. CONCLUSION

Buildings produce large ecological and climate change impacts from their functioning, and also from the embodied energy contained in their building materials. Society must reduce these impacts to avoid the worst forecasts of climate change. This paper presents reductive and restorative sustainability solutions to address the ecological impacts of the built environment. To solve the unfolding global warming crisis and other ecological challenges, architects and built environment practitioners need accurate tools in their armoury. They must be fully primed and ready for use.

Architects, policymakers, designers, engineers and other built environment practitioners responsible for urban outcomes need to refocus their policy, design and building strategies. They need to move towards ecobalanced, lean, low-carbon materials and strategies. Past practice has focused on reductive sustainability exhibited by the 'three Rs' mantra ('Reduce, Re-use, Recycle). It is time to expand sustainability practice to include restorative sustainability and to embrace the concept of the Five Rs: Reduce, Re-use, Recycle, Repair and Restore.

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