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Design for disassembly: support for urban sustainability in Australia

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ABSTRACT

Industrial ecologists recognise the impact of industry upon the environment and develop methods with which to reduce these including the reuse and recycling of materials incorporated into products. Worldwide, the reduction of natural resource consumption has been investigated and applied to various industries, with varying degrees of success. This paper focuses on the construction industry, using thematic analysis to locate world's best practice in respect to construction and demolition waste legislation. It identifies the Netherlands and Denmark as the current leaders in construction and demolition waste management and reports on the results of a policy analysis, which concludes that landfill levies, landfill material bans, material segregation and certification are the main contributors to waste reduction. A meta-analysis of Australian state legislation reveals that these policies are largely absent, rendering the legislation ineffective. A model of legislative best practice is presented that is applicable to the Australian context, which incorporates the concept of designing for disassembly, a technique that already exists in other manufacturing industries. The paper concludes that by implementing these policies there is a potential to decrease waste through reuse and recycling within the building industry.

Key words: Recycling, Policy, Disassembly, Construction and Demolition Waste, Landfill

INTRODUCTION

The large quantity of waste produced by the demolition of residential and industrial buildings presents an increasingly significant challenge for governments around the world. It has been estimated that the U.S. and Western Europe alone produce “half a tonne of construction waste and demolition debris per capita annually”(Knecht 2004). Australia is one of the worst offenders in terms of solid waste sent to landfill. Each year it produces almost 1 tonne per person or approximately 14 million tonnes of waste with between 16% to 40% of this being associated with construction and demolition (Reddrop, Ryan and Walker-Morison 1997, Australian Bureau of Statistics 2003). It has been determined that of this waste material 10% is reused, a further 60% is recycled and the remaining 30% deposited in landfill (Graham, Prasad and Blair 2003).

As understanding of the environmental impact of the consumption of energy and materials increases, more emphasis is being placed upon the recycling or reuse of construction and demolition waste (Crowther 2000b). Aside from the lack of room for landfill, which is the common destination for waste, the main concerns are the harmful leachate and contaminants now recognised to be produced by construction and demolition waste, ground water contamination, the continuous drain upon the environment, and its ability to continue to sustain our requirements. It is this ultimate issue of sustainability that drives the continual reassessment and reform of waste disposal and, where necessary, the policies relating to it.

The challenge facing the Australian government is how to reduce the amount of construction and demolition waste and what to do with waste that is considered unavoidable (Teo and Loosemore 2001). Kibert and Chini (2000) found that the reduction of waste can be achieved through changes in building design and government policy. They state that for this to succeed issues such as design for disassembly and building codes that require such consideration must be addressed. Teo and Loosemore (2001) believe there are three options for managing unavoidable waste: reuse, recycling and disposal. They contend that the balance between these options must be driven by the legislative requirements for particular materials, which in turn reflect the types of materials being wasted and the viability of each recovery/disposal process with regard to cost.

It is common for developed countries to have legislation regarding waste management: some of these are stand-alone policies relating to a single country such as those found in Canada and the US, while others are developed under the umbrella of a unified agreement, such as that in force across the European Union (EU) member states (Vercruysse 2004). There is not, however, international agreement upon best practice in regards to construction and demolition waste disposal. In the US, 92% of their 136 million tonnes of construction and demolition waste is usually placed in landfill (Kibert and Chini 2000). In contrast, the

Netherlands produces 18 million tonnes of construction and demolition waste per year of which 90% is recycled, reused or incinerated (Kibert and Chini 2000, VROM 2001). Demark and Belgium also recycle or reuse 90% of their building waste (Dorsthorst te and Kowalczyk 2003). With a recycling or reuse rate of 70% it is apparent that Australia can learn from international best practice.

BACKGROUND

Industrial ecologists have recognised the impacts of industry upon the environment and have developed methods with which to reduce these impacts including material substitution, recycling and waste mining. However within the construction industry these ideas have not been investigated thoroughly: “If the once-through life-cycle (figure 1) of resource use that dominates the construction industry is replaced with a true cycle in which materials and components are reused, the environmental impact of the industry could be drastically reduced” (Crowther 2000a).

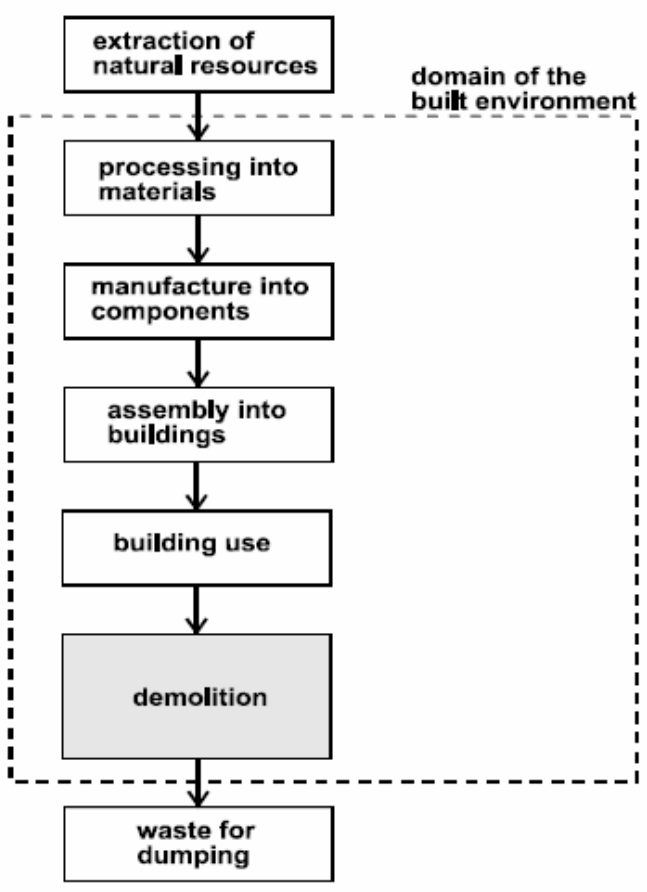

Figure 1: Dominant life cycle of the built environment

The possibilities for the disposal of construction and demolition waste range from recycling to land filling. The full hierarchy (figure 2) depicts the philosophy common throughout Europe, America and Australia. It focuses on the minimisation of environmental damage and resource consumption (Peng, Scorpio and Kibert 1997).

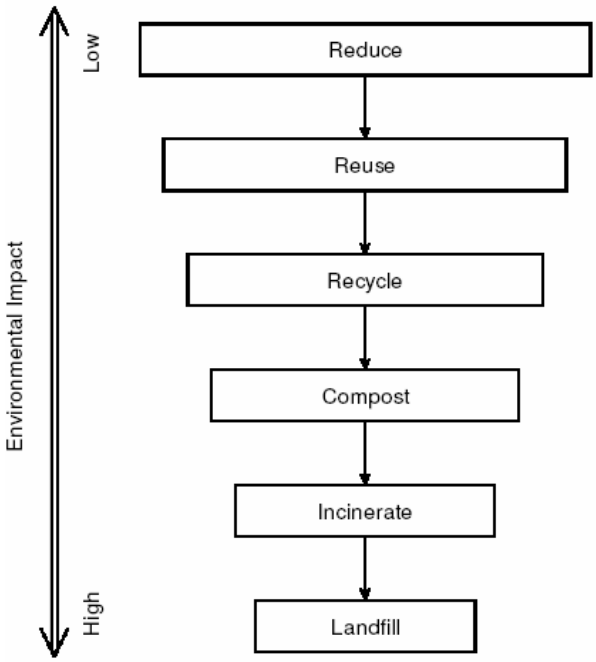

Figure 2: Hierarchy of construction and demolition waste disposal (Peng, Scorpio and Kibert 1997)

Within the EU construction and demolition waste accounts for approximately 34% or 180 million tonnes of all waste produced annually (Vercruysse 2004). Of this amount 130 million tonnes are sent to landfill or incinerated. Between member states recycling percentages vary from less than 5% to approximately 90% (Dorsthorst te and Kowalczyk 2003). The difference in rates can largely be attributed to legislative variations between member states. The most stringent reuses/recycles 90% of it's construction and demolition waste and has made it illegal to dump any materials on landfill that can be recycled or reused (VROM 2001, Dorsthorst te and Kowalczyk 2003).

Waste generated from construction and demolition in Australia has also been recognised as a major issue (McDonald and Smithers, 1998: Lingard, Graham and Smithers, 2000: Teo and Loosemore, 2001: Saunders and Wynn, 2004). As a member of the Australian and New Zealand Environment Conservation Council (ANZACC) formed in 1992, Australia committed itself to the 50% reduction in solid landfill waste by the year 2000, with 40% consisting of construction and demolition

waste (McDonald and Smithers, 1998: Crowther 2000b). The States and Territories then proceeded to set their individual targets (Newton, 2001).

The Federal Government's initiatives included the WasteWise Construction Program, an agreement with five major building companies that attempted to identify best practice in waste prevention or reuse (Bell and McWhinney, 2000). The Government is also responsible for producing the Building Code of Australia, the primary regulatory instrument governing the construction of new and refurbished buildings, although this code does not mention or reference recycling, reuse of materials or the concept of deconstruction (Crowther, 2000b). The NSW Department of Environment and Conservation, formerly known as the Environmental Protection Authority (EPA), has begun to target construction and demolition waste but confines it's attention to government-funded projects (DEC [NSW], 2005). Whilst the Commonwealth Government has stated its wish to improve Australia's reuse and recycling within the construction industry, any initiatives, guidelines or policies have been ambiguous and broad in relation to construction and demolition waste, with the majority of the responsibility falling to the States, Territories and local government (Crowther, 2000b).

A popular theory for the avoidance or reduction of construction and demolition waste is the design for disassembly or deconstruction of buildings. Disassembly is, as it sounds, the reverse of assembly, and would require a similar amount of time and effort and (reverse) construction sequence. However this would lead to the ability to recycle or reuse the construction components (Crowther, 2002). Disassembly offers advantages over traditional demolition including the "diversion of waste from landfill areas, increased ease of material recycling and enhanced environmental protection" (Kibert and Chini, 2000). The theory has been successfully put into practice in areas of the manufacturing industries (Bylinsky, 1995) 'Zero landfill' is becoming widely embraced and is based on the idea of a closed loop system where products are regarded as valuable resources and an all out effort is made to re-utilise them

These examples highlight the potential that design for disassembly techniques present: it is apparent that these techniques have potential within the construction industry (Crowther, 2000a).

Research conducted in America indicates that the most effective method for the implementation of a design for disassembly strategy into the construction industry is through government policy (Kibert and Chini, 2000). Other research suggests that the Netherlands and Denmark have set a benchmark in terms of construction and demolition waste management with reuse/recycling rates of around 90%. In comparison Australia lags behind with a comparable rate of 70%.

This raises a number of important questions.

- Firstly, do these European nations represent the model of world's best practice, and if they do;
- To what extent is this driven by statutory regulation that encourages design for disassembly strategies?
- Furthermore, in terms of policy, how does Australia compare to the rest of the world, and;
- Can lessons be learnt from other nations and successfully applied in an Australian context?

RESEARCH PROCESS

Preliminary analysis of the relevant literature highlighted the current situation in terms of construction and demolition waste disposal in Australia and identified the need for change. The analysis also identified a range of mechanisms to improve the situation, and also indicated that policy and legislation provided the most appropriate drivers to change. Therefore this research set out to model world's best practice in respect to construction and demolition waste legislation for application in Australia. The objectives were therefore firstly, to develop an appropriate methodology for identifying and analysing suitable policy documents and other relevant sources in order to identify current construction industry practices in waste management as well as techniques used in non-construction industries. Secondly it examined the Australian Federal Government's current policies on construction and demolition waste in order to conduct a legislative gap analysis, and thereafter propose recommendations for improvement. This was achieved through a comparative policy analysis between Australia and those nations considered to be the benchmark of international best practice, namely Denmark and the Netherlands. Particular focus was provided on recent literature that discussed the potential developments in the reduction of construction and demolition waste through the use of design techniques for disassembly. Consideration was give to their 'portability' and applicability in an Australian context.

As this study was based on the analysis of documentation it was qualitative in nature, involving the studied collection and use of a variety of empirical materials (Denzin and Lincoln, 2003) and approached the subject matter in a naturalistic and interpretive manner. Given the multiple initiatives identified meaningful comparison between them had to be made on the basis of thematic analysis, allowing common trends to emerge from the research team's understanding of the documents. However, prior to this an initial policy analysis was conducted and used to support the alternatives identified under each thematic heading. These processes and their interrelationships are illustrated in Figure 3.

POLICY ANALYSIS

A policy analysis was conducted to understand the current construction and demolition waste policies to identify those countries thought to demonstrate best practice. Crowther (2000b) used a similar method with success for his study on the recycling policies of Australia. As a research method policy analysis had been described as "the process through which we identify and evaluate alternative policies or programs that are intended to lessen or resolve social, economic, or physical problems" (Barrientos, 1999). This would typically be conducted through document analysis (London, 2006). The relevant information that could be made available by this research method included policy evaluation and formulation (Ezzy 2002).

The policy information for the countries representative of best practice was collected using internet based government policy websites on waste management. The data collected was then organised using the levels of importance imposed upon them by the respective governments and subsequently compared and categorised. In order to temper any bias in these sources secondary documentation including journal articles and conference proceedings were used to corroborate the validity of the information. The results of this policy analysis were used as the framework against which comparison with Australian policy was made.

A similar process was undertaken to deal with the topic of Australian waste management using policy websites, journals, conference proceedings and government reports. However, this analysis focused directly upon the criteria determined by the analysis of waste management best practice. The results documented the similarities and differences between the countries and were used to provide an indication of those areas of policy requiring improvement.

A comparison of the results of the thematic analysis of recent developments within waste management and the findings of the policy analyses were used to develop and validate a model of construction and demolition waste management considered to represent a viable future direction for Government policy.

THEMATIC ANALYSIS

Initial research into industrial ecology using construction based journals highlighted the negative impact of construction and demolition waste on the environment. A thematic analysis was then conducted to further investigate this research area. By definition, thematic analysis is the process whereby “concepts, categories and themes are identified and developed while the research is being conducted” (Ezzy, 2002). Rather than beginning with a hypothesis to be tested this research used thematic analysis to identify the salient issues that then guided the subsequent gathering of information and development of theory (Kellehear, 1993: Ezzy, 2002).

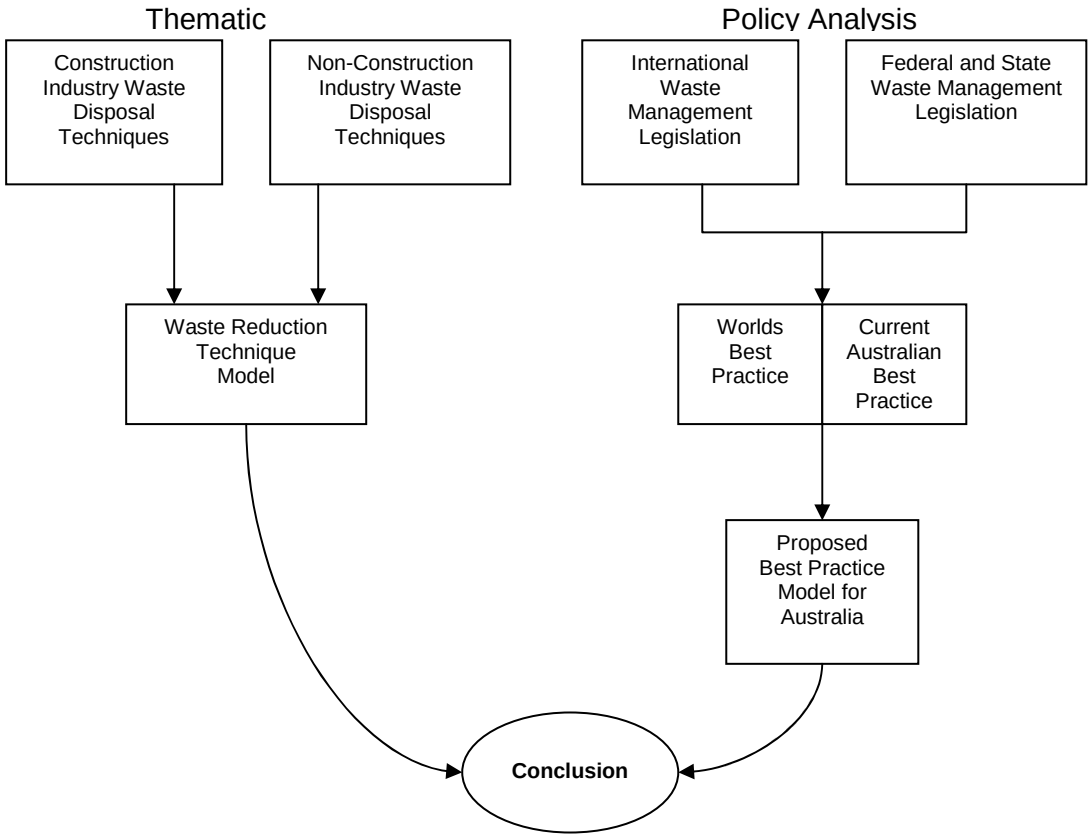

Figure 3: Research process

The analysis initially focused upon the current waste output performance of Australia and various other countries around the world. The choice of countries was based upon the ability to obtain accurate and credible information from statistical bureaus, peer-reviewed journals, conference proceedings and commonly referenced works from within these sources. This analysis was used to ascertain the countries of best waste management practice.

At this point the research split into two sections, continued thematic analysis and a policy analysis. The thematic analysis began to look at the current literature on recent developments of waste management practices in industries outside of construction. The theory of design for disassembly emerged as an important feature from this analysis. Various companies were analysed using data collected from their own websites, supported by journal articles. The usefulness of this information was not solely based upon the companies claimed success but in the fact that their experiences were achievable, verifiable and potentially transferable to the

construction industry. By this process a theoretical framework was developed for designing for disassembly. This framework was then added to the current methods of waste management, thus echoing Manuel (2003) who successfully used a similar method when investigating environmental concerns of waste disposal and management .

RESULTS

The Netherlands

Political and social resistance in the late eighties forced the Netherlands government to shelve the planning and construction of more landfill and incinerating sites. This meant that for some time inland barges were used to store waste. These factors were the main factors driving the development and implementation of their National Waste Management Plan (VROM, 2003).

The main objective of the Dutch National Waste Management plan is the prevention and recovery of all waste, including construction and demolition waste. This has led to a recycling rate of 90% (VROM, 2001). Recovery is a term used to describe reuse and recycling. If recovery is not an option, then waste can be used for fuel. This order of preference runs down from waste prevention through to landfill disposal and is based upon Landsink's Ladder (VROM, 2003), developed in 1985. The main policies within the National Waste Management Plan encouraging prevention and recovery of construction and demolition waste are:

- The Building Materials Decree – helping to promote a healthy product market
- The financial incentive of the Environmental Taxes Act
- The Waste Substances (Prohibition of Landfill) Decree (VROM, 2001)

Building Materials Decree

A crucial element in the reduction of construction and demolition waste in The Netherlands was ensuring that there was a market for the secondary materials produced from waste. This led to the introduction of the Building Materials Decree, developed to give customer confidence in the products.

The Building Materials Decree (BMD) is a regulation based upon the prevention of soil and surface water pollution and came into full operation on 1st July 1999 after an introductory period of three years. It was introduced in response to the Waste Management legislation that enforces the reuse and recycling of materials as much as possible. As this reuse has become customary, it was necessary to apply quality standards to the reused materials (Eikelboom,et al, 2001).

The BMD provides quality criteria for the application and reuse of stony material and earth used as building material. The decree makes no differentiation between primary materials, newly extracted or produced products, and secondary materials, those which come from demolished structures. All materials must conform to the required standards and be properly certified (VROM, 2006).

In terms of being considered a successful policy for the reduction of construction and demolition waste, the implementation of the BMD has greatly improved the levels of recycling of secondary materials in the the Netherlands and has helped in bringing the level of reuse of materials to 90% (Eikelboom et al, 2001).

Environmental Taxes Act
The Dutch Environmental Taxes Act for waste management gradually increased the level of taxation of waste sent to landfill until 2002. At this point landfill tax per tonne was more expensive than the government's desired alternatives of recovery or incineration. This meant that a "significant financial incentive had thus been created to use building and demolition waste beneficially" (VROM, 2001).

Waste Substances (Prohibition on Landfill) Decree
Implemented in 1997, the Waste Substances (Prohibition on Landfill) Decree banned all landfill of recyclable waste products produced by construction and demolition. An extension was added to this ban to include any construction and demolition waste which was combustible, although this ban has been softened until there are enough incinerators to cope. Once this situation has been rectified, the only construction and demolition waste sent to landfill will be non-combustible and non-recyclable waste on which high tax is paid (VROM 2001).

Denmark

The construction and demolition waste recycling level of Denmark in 1993 was 50%, with 23% going to incineration and energy recovery, and 27% being sent to landfill. Realising this was a misuse of valuable resources and that landfilling was having a polluting affect upon the countries groundwater system, which provided 98% of Denmark's water supply, high priority was given to waste management (Hjelmar, 1996). Current figures indicate that Denmark has achieved a recycling level of 90%, incineration levels of 2% and landfill levels of 8% (EPA, 2006).

The Danish model of waste management and waste policy was developed by the Ministry for the Environment and the Environmental Protection Agency (EPA) and is called the Environmental Protection Act. This act is formed around the Danish hierarchy of waste management priority of options: "recycling ranks higher than incineration with energy recovery, and landfilling ranks lowest" (EPA, 2006). Relevant to construction and demolition waste are the acts that aim to prevent and combat

pollution, promote recycling and limit waste disposal and to restrict the use and waste of raw materials (Hjelmar 1996). The tools to enforce the Act's policies include:

- The Landfill Prohibition Order
- Waste tax as a financial incentive
- Waste Separation Circular

Landfill Prohibition Order
The landfill prohibition order was introduced into Denmark in 1997 by the EPA. The order prevented the landfilling of any substance or waste product suitable for incineration, thus ensuring the recovery of energy contained in the waste and preventing groundwater pollution. The future plan for this policy is to shift the focus from incineration to recycling (EPA, 2006).

Waste Tax
In 1993 Denmark introduced its Waste Tax, an economic instrument designed to reduce all waste, including construction and demolition waste. It is a hierarchical system that differentiates between wastes for recycling, wastes for incineration and waste that go directly to landfill. Waste sent to landfill is the most expensive; recycled waste is tax exempt (EPA, 2006). This tool coupled with landfill prohibition leads to the consideration of waste prevention.

Waste Separation Circular
The Waste Separation Circular is an agreement between the Minister for Environment and Energy, the EPA, Local Authorities, the Danish Construction Association and the Danish Demolition Association. The Circular, effective from 1997, states that "in demolition works involving more than 1 tonne of construction and demolition waste, waste shall be separated at source in clean fractions" (EPA, 2006). The ability to recycle more waste materials has improved through the implementation of the circular.

Criteria

The analysis of the management of construction and demolition waste legislation and policies of The Netherlands and Denmark has indicated two areas of commonality and two areas of difference. As the intention of the analysis was to assess successful practice, all these areas will be included in the criteria formed to measure Australian construction and demolition waste practice against the worlds leading performers. The criteria are as follows together with their salient aims:
Landfill Levy – landfill is the most expensive option with recycled materials exempt
Landfill Material Ban – ban on dumping all recyclable waste
Material Certification – developing material standards or certification to allow for reuse
Material Segregation – segregation of materials allows for more extensive recycling

Australian Policy Analysis

The responsibility for waste management in Australia straddles three different levels of government: local, State and Federal. The Federal Government has provided the framework for policy direction by setting targets for waste reduction through ANZACC agreements, overseen in Australia by the Environment Protection and Heritage Council (EPHC). Local governments are responsible for waste collection and the providing of waste and recycling facilities. In general though, it is the state governments who regulate waste management, including construction and demolition waste. With so many parties involved in the process “the waste management policy for Australia is for the most part, poorly coordinated”(Productivity Commission, 2006). Table 1 outlines the State waste management and recycling legislation and policies for construction and demolition waste in selected states.

In order to analyse Australia’s construction and demolition waste policies in relation to identified best practices of The Netherlands and Denmark it is necessary to view Australia through state policy, focusing on the criteria identified above. As statistical information of construction and waste production was not available for Tasmania, the Northern Territory and the Australian Capital Territory, they have not been included in the analysis

Table 1: Australian state waste management and recycling legislation and policies

State	Legislation	Policy
New South Wales	Waste Minimisation and Management Act 1995 Protection of the Environment Operations Act 1997 Protection of the Environment Operations Act (Waste Regulations 2005)	Construction and Demolition Waste Action Plan 1998 Waste Reduction and Purchasing Policy (WRAPP) 1997 NSW Waste Avoidance and Resource Recovery Strategy 2003
Victoria	Environment Protection Act 1970	EcoRecycle Victoria Towards Zero Strategy
South Australia	Environment Protection Act 1993	Environment Protection (Waste Management) Policy 1994 Zero Waste Strategy
Queensland	Environment Protection Act 1994	Waste Management Strategy for Queensland 1996
Western Australia	Environmental Protection Amendment Act 1998 Environmental Protection (Landfill) Levy Act 1998	Waste Reduction and Recycling Policy Waste 2020

New South Wales State Government

The primary pieces of waste management legislation used in NSW are the Waste Minimisation and Management Act 1995, the Protection of the Environment Operations Act (Waste Regulations 2005), which is supported mainly by Waste Reduction and Purchasing Policy (WRAPP) 1997, and the NSW Waste Avoidance and Resource Recovery Strategy 2003. The current recycling rate for construction and demolition waste is 65% and the aim of these policies is to increase this figure to 75% by 2014 (Resource NSW, 2003).

Landfill Levy

The NSW landfill levy on construction and demolition waste is currently $15 (rural) and $22.70 (metro) although there are plans to increase the levy to $57 by 2012. It is believed this increase in revenue will provide a boost to technologies aimed at achieving the States waste targets. These target levies are based on NSW industry recommendations. Working alongside the levy system is the rebate from waste levy, which can be claimed if the waste leaves the facility recycled or genuinely reused (Productivity Commission, 2006).

Landfill Material Ban

There are no legislations or policies prohibiting the landfilling of recyclable construction and demolition waste in NSW. The Waste Production and Purchasing Policy (WRAPP), directed towards all state owned agencies and corporations, provides the closest comparison. This policy requires these bodies to provide data on the waste types generated and the amount that is recycled. These data are used to produce recommendations for improvement (DEC [NSW], 2006).

Waste Segregation

There are no current legislations or policies in place with regards to waste separation. WRAPP does recommend its implementation.

Material Certification

There are no current legislations or policies in place with regards to material certification. WRAPP recommends the use of recycled products, but leaves it to the purchaser to ensure it meets the required engineering specifications (DEC [NSW], 2006).

Victorian State Government

Victorian State legislation for waste management is the Environment Protection Act 1970, reinforced by the policies of EcoRecycle Victoria and the Towards Zero Strategy. In 2004-2004 Victoria produced approximately 3.1 million tonnes of construction and demolition waste, with 57% being recycled. The intent of the current policies is to increase this rate to 80% by the year 2014 (EcoRecycle Victoria, 2005).

Landfill Levy
Victoria has introduced higher levies on construction and demolition waste, seemingly to divert and reduce the size of that waste stream. It would be more accurate to say however, that this revenue is to used fund the waste management program EcoCycle (Productivity Commission, 2006).

Landfill Material Ban
There are no current legislations or policies prohibiting the landfilling of recyclable construction and demolition waste in Victoria. The closest comparison is the governments in-house purchasing procedure which address the issues of waste production management and recycling in regards to what can be put into landfill (EcoRecycle Victoria, 2005).

Waste Segregation
There are no current legislations or policies in place with regards to waste separation. The Towards Zero Strategy identifies this as an area requiring attention (EcoRecycle Victoria, 2005).

Material Certification
There are no current legislations or policies in place with regards to material certification. The Towards Zero Strategy identifies the need to provide a market for recycled products (EcoRecycle Victoria, 2005).

South Australian State Government

The Environment Protection Act 1993 is South Australia's primary waste management legislation supported by the Zero Waste Strategy policy. With the current recycling rate of construction and demolition waste at approximately 55%, the intent is to increase this figure to 100% with the implementation of this strategy (Zero Waste SA, 2005).

Landfill Levy
No distinction is made between construction and demolition waste and municipal waste in the landfill levies. The main purpose for this levy is to fund their waste management program as opposed to reducing landfill (Productivity Commission, 2006).

Landfill Material Ban
There are no current policies or legislations in SA to prohibit the landfilling of recyclable construction and demolition waste. The proposed Zero Waste Strategy is intended to prevent the dumping of waste that includes recyclable product by providing appropriate infrastructure and a well established market. (Zero Waste SA, 2005).

Waste Segregation
There is no current legislation or policy in place with regard to waste separation. The Zero Waste Strategy policy states that it will encourage waste segregation where practicable (Zero Waste SA, 2005).

Material Certification
There is no current legislation or policy in place with regards to material certification. The Zero Waste Strategy policy proposes strategies for encouraging the use of recycled materials through the establishment of quality standards for recycled products (Zero Waste SA, 2005).

Queensland

Waste management for Queensland is controlled by the Environment Protection Act 1994 and supported by the Waste Management Strategy for Queensland 1996 policy. The current construction and demolition waste recycling figure for the State is 42% (Productivity Commission, 2006).

Landfill Levy
There are no current levies upon construction and demolition waste disposal in Queensland (Crowther, 2000b).

Landfill Material Ban
There is no current legislation or policy in Queensland to prohibit the landfilling of recyclable construction and demolition waste. The closest comparison can be made with the Government's in-house waste management strategy objective where the demolition of a government building or any site redevelopment by a government agency will, where practicable, include a waste recovery program for all reusable materials (Crowther, 2000b).

Waste Segregation
There are no current legislations or policies in place with regards to waste separation

Material Certification
There is no current legislation or policy in place with regards to material certification.

Western Australia

The primary pieces of legislation for waste management in Western Australia are Environmental Protection Amendment Act 1998, and the Environmental Protection (Landfill) Levy Act 1998. These are supported by the Waste Reduction and Recycling Waste Policy 2020. In 2003-2004 the recycling rate for construction and demolition waste was 21%, and it is the intent of the WA government to increase this to 100% by the year 2020 (Productivity Commission, 2006).

Landfill Levy
The landfill levies of Western Australia are used to fund their waste management program. By its own admission, the Western Australian Department of the Environment has stated that "while a landfill levy may act as a moderate disincentive for disposal to landfill in some circumstances e.g. for construction & demolition waste, its main benefit is to raise revenue to support waste reduction initiatives" (Productivity Commission, 2006).

Landfill Material Ban
There is no current legislation or policy prohibiting the landfilling of recyclable construction and demolition waste in Western Australia.

Waste Segregation
There is no current legislation or policy in place with regards to waste separation

Material Certification
There is no current legislation or policy in place with regards to material certification.

DISCUSSION
The policy analysis of The Netherlands and Denmark, the two countries which were considered to be exemplars in construction and demolition waste recycling, identified the employment of four major waste management strategies. These were landfill levies, landfill material bans, waste separation and material certification for reuse. Table 2 presents a summary of these findings, making the comparison between world's best practice and five State governments within Australia. It should be noted that it does not give recognition to partial implementation of best practices.

The results indicate that none of the States have current legislation or policies that mirror those identified as world leading. The detailed analysis in the previous section shows that New South Wales is the only state with a policy that partially complies with the landfill levy criteria through the implementation of a rebate scheme.

The research did identify the future intentions of most States to improve their rates of construction and demolition waste dumping. In terms of overall strategy, South Australia's Zero Waste policy most closely resembled best practice, although not to as high a level of inclusion.

The differences in recycling rates between the countries and States is a little surprising given that their overriding philosophies are all very similar. As previously noted, the Netherlands have based their approach upon Lansink's Ladder, and the other jurisdictions under consideration have adopted similar approaches. The waste hierarchy diagram (Figure 5) taken from South Australia's Zero Waste Strategy

(2005), is a reasonable embodiment of the principles underpinning all of the States' waste policies.

Table 2: Australian States in comparison with world's best practice

	Recycling Rate of C&D Waste (%)	Landfill Levy		Material Certification	Material Segregation
		Most Expensive	Landfill Materials Ban (levy exempt)		
The Netherlands	90	√	√	√	X
Denmark	90	√	√	X	√
NSW	65	X	X	X	X
Victoria	57	X	X	X	X
South Australia	55	X	X	X	X
Queensland	42	X	X	X	X
Western Australia	21	X	X	X	X

(VROM 2001, Dorsthorst te and Kowalczyk 2003, Resource NSW 2003, EcoRecycle Victoria 2005, Zero Waste SA 2005, Productivity Commission 2006)

One area that is not directly addressed in the identified best practice criteria is that of waste avoidance. Whilst the policies encourage *ex post* waste avoidance through material bans and high levies, they do not directly engage with the avoidance issue and suggest solutions. This research found that the *ex ante* strategy of designing for disassembly was being used successfully in a range of industries and that it should have a place within construction by the avoidance of waste through careful preparation at the design phase of a product.

Guidelines have to be developed for application in the building industry to assist in designing for disassembly. The following list, produced by Crowther (2000a) identifies and summarises possible improvements to current practice:

- Minimise different types of materials leading to easier sorting for recycling, greater quantities of recycling and simplified transportation.
- Avoid hazardous materials because of the difficulty in treatment and recycling.
- Understand standard recycling practice and recommend materials accordingly.
- Ensure materials are joined in easily separable ways
- Avoid designing with secondary finishes or coatings
- Identify materials using markings that indicate standards would help to increase confidence in reuse

- Keep the number of components to a minimum, creating greater numbers of fewer types of components which improves reuse or recycling
- Design using mechanical connections, bolts and screws, rather than chemicals connections that contaminate materials and make disassembly difficult

As figure 3 illustrates, the implementation of a design strategy with the view to disassembly would alter the existing “once-only” materials life cycle currently common in construction to an alternate, repetitive cycle where disassembly, reuse and recycling were the norm (Figure 4) (Crowther 2000a).

Such a strategy and resultant reduction in construction and demolition waste would pose new challenges creating a built environment where:

- The majority of existing structures and their components would not have been designed for disassembly
- The necessary tools for disassembly would not yet exist
- The current costs for the landfilling of construction and demolition waste would be judged to be too low to act as a deterrent to those practices
- Additional time and consequent cost would be required for the disassembly of buildings and segregation of materials
- The certification of building components would not always be possible
- The existing building codes would not easily accommodate the use of recycled materials or components into new works.

(Crowther 2000a)

The introduction of design for disassembly into the construction industry would alter the waste philosophies discussed earlier. Waste avoidance would replace waste reduction as the strategy of choice. The new design philosophy based on design for disassembly would resemble the proposed waste hierarchy of the South Australian Zero Waste Strategy (2005) (figure 5).

Transplanting design for disassembly principles into a construction industry context presents serious challenges because of the differences between manufacturing and construction. Of particular interest are the following:

- the difficulty of labelling individual components and products with meaningful recycling data
- the high levels of use of generic and composite materials in certain forms of construction
- The disparity between "as designed" and "as specified" documentation, and the "as built" reality, where equal and approved, and unauthorised material/product substitutions occur.

- The lack of a single point of responsibility for coordinating the reuse/recycling process for a particular building.

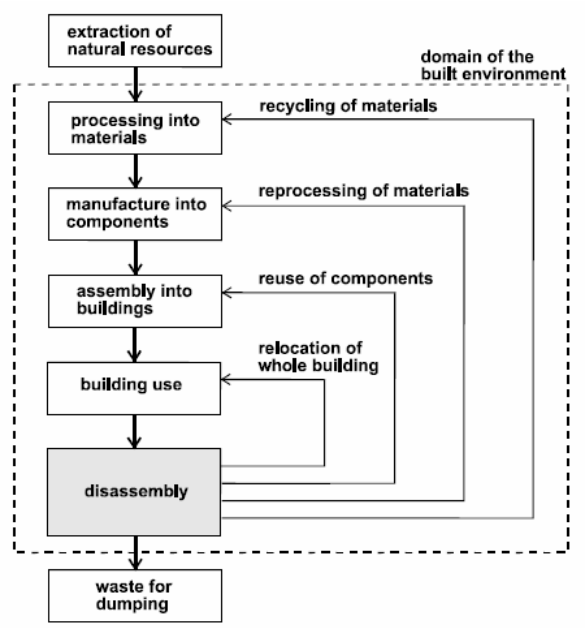

Figure 4 Life-cycle of materials using design for disassembly (Crowther 2000a)

It is also interesting to note that the design for disassembly literature relating to manufacturing (e.g. Beitz, 1993) makes considerable reference to the process of refurbishing items for re-introduction into service. It has long been recognized that the costs associated with the refurbishment of existing buildings tend to be disproportionately high, often rendering the process uneconomic, resulting in the demolition of an old building and construction of a new one in its place.

Certain new technologies have the potential to offer solutions to some of these challenges, in particular:

- The use of 4D CAD models to document and record the "as built" project, including all of the necessary recycling/re-use information relating to materials and products
- The use of bar coding and embedded microchips to label materials and products in-situ within the building (Bulmer and Brewer, 2000).

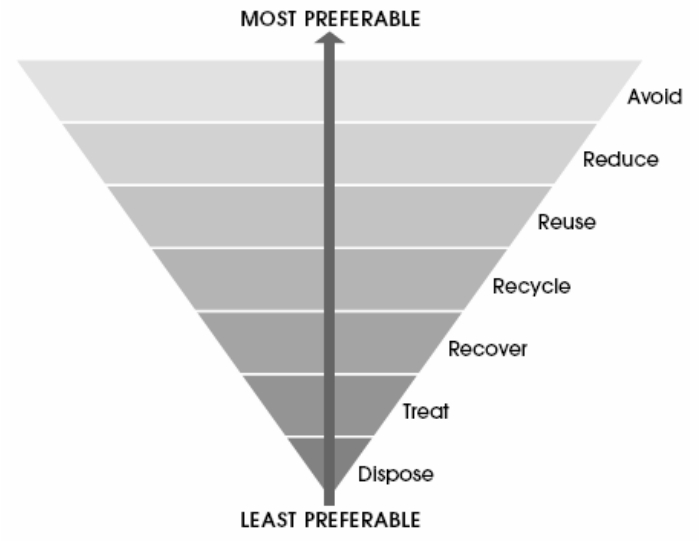

Figure 5: Waste Hierarchy (Zero Waste SA 2005).

CONCLUSION

Industrial ecology has identified the negative impact of construction and demolition waste upon environmental and urban sustainability. This has inevitably meant that more emphasis is being placed upon the recycling or reuse of waste. The poor record of Australia in comparison to other countries can be attributed to the nature of the various governments' policies relating to it.

A policy analysis from around the world has identified both the Netherlands and Denmark as demonstrating best practice, thus setting the benchmark for others. The analysis has identified criteria that can be used to drive a successful waste management strategy for nations such as Australia. These criteria included levy systems to encourage recycling; bans on the disposal of recyclable wastes to landfill; the need for waste segregation or separation; a system of recycled materials certification to encourage the development of markets for their use.

A policy comparison of Australian States found that none had legislation to match the benchmark practices. This result highlights the fact that Federal, State and Local government policies are ambiguous and ineffective in regard to construction and demolition waste management.

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