CHAPTER 2
BUILDING DECONSTRUCTION IN AUSTRALIA
Philip Crowther (Queensland University of Technology, Brisbane, Australia)

SUMMARY

This report presents information on current issues regarding the state of deconstruction in Australia. These issues include; quantities of waste and recycling, embodied energy, policy and legislation, design practice, demolition, initiatives in recycling, initiatives in deconstruction, and current research in design for deconstruction. The report concludes with recommendations for future research and for changes in design practice and government policy.

As an industrialised nation Australia has achieved high levels of consumption and correspondingly high levels of waste disposal. The construction industry is a major contributor to these levels of waste creation and consequently a major potential market for reused and recycled materials. Recent government policies have attempted to address aspects of these issues but as yet they are neither wide reaching enough nor coordinated enough to have any real effect.

The recycling of small scale residential building materials is well established and high rates or reuse are achieved, but this is not the case for commercial and industrial buildings where the only major recycling to occur is the crushing of concrete for aggregate.

There is some research in Australia into recycling technologies, issues of embodied energy, and design for deconstruction. This research is not however well integrated with the construction industry in general. Deconstruction, like other environmentally sustainable issues, is at present an interesting concept that fails to achieve wide spread understanding or implementation.

KEYWORDS: Australia; Disassembly; History; Policy; Recycling; Technology.

ACKNOWLEDGEMENTS

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2.1 INTRODUCTION

Australians have one of the highest standards of living in the world. Unfortunately part of the price that is paid for this standard is major environmental degradation. Current industrialised practice in Australia, as in many parts of the world, results in the production of large amounts of waste. A major part of this waste is the result of building demolition. This problem has only recently received attention. Government policy, building practice, and design education are now starting to address the issues of waste associated with the built environment and in particular demolition.

Deconstruction, the systematic taking apart of a building for the purpose of materials reuse as
opposed to destructive demolition, is not a new concept, but it has not previously been the topic of research in Australia. This report presents the current state of building deconstruction in Australia. It is a compilation of information from many sources and relies heavily on related research.

**Information Sources**
The information presented in this report has been sourced through contact with: government departments - including Environmental Protection Agencies in each state; universities and academics - including all universities with architecture schools; government and private research organisations; and a literature review of the field.

### 2.2 QUANTITIES OF WASTE AND RECYCLING

Australia, as an industrialised nation, consumes large amounts of materials and energy and produces large amounts of waste and pollution per capita. The creation and maintenance of the built environment is responsible for a major part of this consumption and production.

The role that demolition plays in this waste production scheme is unclear, as is the role of recycling and reuse. It can be seen below, that there is no comprehensive understanding of the quantities and types of demolition waste and recycling, but rather a scattering of research studies in small scale.

**Quantities of Waste**
Australia has one of the highest rates of solid waste disposal in the world. Nearly one tonne of solid waste is sent to landfill per person each year, approximately 14 million tonnes [1]. Of this the amount, construction and demolition waste has been measured and estimated at from 16% to 40% [2] [3].

**Type and Sources of Waste**
There is no Australia wide research into the types and sources of construction or demolition waste. There are however some recent isolated local studies. Research has been conducted in Melbourne to investigate the sources of demolition waste and the quantities of waste that are recycled [4], see Table 1.

Table 1 Amount of demolition waste in Melbourne 1993 by building type, in tonnes per m² of floor area.

<table>
<thead>
<tr>
<th>BUILDING TYPE</th>
<th>MEAN WASTE t/m²</th>
<th>MAXIMUM WASTE t/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential detached</td>
<td>0.5</td>
<td>2.3</td>
</tr>
<tr>
<td>Residential other</td>
<td>1.2</td>
<td>6.3</td>
</tr>
<tr>
<td>Residential total</td>
<td>0.7</td>
<td>6.3</td>
</tr>
<tr>
<td>Non residential total</td>
<td>0.6</td>
<td>2.0</td>
</tr>
</tbody>
</table>

In another study, published in 1998, EcoRecycle Victoria conducted a series of surveys at landfill
sites to identify quantities and type of solid waste in the Melbourne metropolitan area [5]. Construction and Demolition waste was estimated at 40% of the volume of total landfill waste. The sources of construction and demolition waste are presented in Table 2, and the type of materials presented in Table 3.

Table 2 Percentage of construction and demolition waste in Victoria by building type.

<table>
<thead>
<tr>
<th>BUILDING TYPE</th>
<th>PERCENTAGE OF TOTAL C&amp;D WASTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential demolition</td>
<td>39.3</td>
</tr>
<tr>
<td>Commercial demolition</td>
<td>33.3</td>
</tr>
<tr>
<td>Residential construction</td>
<td>10.5</td>
</tr>
<tr>
<td>Commercial construction</td>
<td>4.9</td>
</tr>
<tr>
<td>Civil construction</td>
<td>4.0</td>
</tr>
<tr>
<td>Road and landscape</td>
<td></td>
</tr>
<tr>
<td>construction</td>
<td>1.7</td>
</tr>
<tr>
<td>Road and landscape</td>
<td></td>
</tr>
<tr>
<td>demolition</td>
<td>1.2</td>
</tr>
<tr>
<td>Civil demolition</td>
<td>0.8</td>
</tr>
<tr>
<td>Other</td>
<td>4.3</td>
</tr>
</tbody>
</table>

Table 3 Percentage of total solid waste in Victoria by material type (building materials only).

<table>
<thead>
<tr>
<th>MATERIAL TYPE</th>
<th>PERCENTAGE OF TOTAL SOLID WASTE STREAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timber and wood</td>
<td>26</td>
</tr>
<tr>
<td>Concrete</td>
<td>14</td>
</tr>
<tr>
<td>Brick</td>
<td>6</td>
</tr>
</tbody>
</table>

While this research shows timber as a major contributor to the solid waste stream, many other research projects suggest that concrete and masonry represent the major portion of construction and demolition waste, at least 75% [6]. With no Australia-wide data, comprehensive figures of overall demolition waste quantities and types can only be estimated from the data of local studies.

**Quantities of Recycling**

Australia wide figures for the recycling and reuse of construction and demolition material are similarly not available, but some local research has been conducted. Generally, reuse and recycling of residential building materials is much higher than for commercial and industrial buildings, with most states having well established markets for second-hand residential components and materials [7].
For example, in Brisbane, the traditional detached timber house has achieved high levels of popularity in inner city suburbs. As such there is a well-developed market for reused doors, windows, floorboards, wall lining boards, framing, and the like, to be used in residential restoration, renovation and in new replica character housing. These activities extend to whole house relocation, (discussed later). This trend in reused materials is however generally limited to niche markets.

It should be noted that the construction technology used in these houses (typically from 70 to 100 years old) is very conducive to their deconstruction. These buildings are primarily made from standard dimensional lumber, nailed in place, with a very limited amount of ‘wet’ trade work (such as plastering, concreting, tiling). The technology used in contemporary houses by comparison may be considerably less conducive, particularly with modern glues and sealants, and increased reliance on ‘wet’ trades.

Figure 1 Typical timber house built in 1920’s, now derelict and awaiting relocation or deconstruction for materials recycling.

Research in Melbourne has shown quite high rates of material reuse and recycling of residential building materials [8]. This survey, though of a relatively small sample, shows percentages of building components and materials that were recovered for reuse by residential demolition companies, Table 4.

Table 4 Percentages of materials by weight recovered from residential building demolition in Melbourne, and the type of recovery (as the number of traders out of the total surveyed).

<table>
<thead>
<tr>
<th>TYPE OF MATERIAL</th>
<th>TOTAL PERCENTAGE RECOVERED</th>
<th>REUSED OR RENOVATED</th>
<th>RECYCLED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brick</td>
<td>77</td>
<td>10/10</td>
<td>-</td>
</tr>
</tbody>
</table>
As well as the recycling and reuse of demolition materials there is a large market for relocating whole houses. Timber houses are regularly cut into large sections to be transported to new sites for reassembly and reuse. Research has suggested that as many as 1000 houses a year are relocated in the Melbourne district alone, which has a total housing stock of 800,000 detached houses [9]. This practice is certainly not limited to Melbourne, and similar rates of relocation could be expected in other areas.

The same research shows that while rates of recovery in residential building demolition are quite high, commercial office building demolition results in much lower rates of recovery [10]. The study also shows that while the majority of materials and components from residential salvage are reused in their existing state, the majority of materials from commercial salvage are recycled or reprocessed, Table 5.

Table 5 Percentages of materials by weight recovered from CBD office building demolition in Melbourne, and the type of recovery.

<table>
<thead>
<tr>
<th>TYPE OF MATERIAL</th>
<th>TOTAL PERCENTAGE RECOVERED</th>
<th>REUSED</th>
<th>RECYCLED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>70</td>
<td>-</td>
<td>70</td>
</tr>
<tr>
<td>Brick and tiles</td>
<td>75</td>
<td>60</td>
<td>15</td>
</tr>
<tr>
<td>Structural steel</td>
<td>95</td>
<td>15</td>
<td>80</td>
</tr>
<tr>
<td>Steel reinforcing</td>
<td>50</td>
<td>-</td>
<td>50</td>
</tr>
<tr>
<td>Timber &amp; timber products</td>
<td>50</td>
<td>50</td>
<td>-</td>
</tr>
<tr>
<td>Cast iron pipe</td>
<td>80</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Concrete block</td>
<td>25</td>
<td>25</td>
<td>-</td>
</tr>
<tr>
<td>Copper</td>
<td>90</td>
<td>-</td>
<td>90</td>
</tr>
<tr>
<td>Aluminium</td>
<td>90</td>
<td>-</td>
<td>90</td>
</tr>
<tr>
<td>Screenings</td>
<td>80</td>
<td>20</td>
<td>60</td>
</tr>
<tr>
<td>Other</td>
<td>5</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>69</strong></td>
<td><strong>11</strong></td>
<td><strong>58</strong></td>
</tr>
</tbody>
</table>

Also in Victoria, EcoRecycle Victoria provides some information on quantities and types of
materials that were recycled in 1996, including construction and demolition waste, see Table 6 [11].

Table 6 Quantities of building materials recycled in Victoria in 1996.

<table>
<thead>
<tr>
<th>TYPE OF MATERIAL</th>
<th>QUANTITY RECYCLED in tonnes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>748,000</td>
</tr>
<tr>
<td>Steel</td>
<td>630,000</td>
</tr>
<tr>
<td>Brick and brick rubble</td>
<td>102,000</td>
</tr>
<tr>
<td>Timber</td>
<td>12,000</td>
</tr>
<tr>
<td>Plaster</td>
<td>10,000</td>
</tr>
</tbody>
</table>

In Sydney, where demolition waste represents approximately 43% of the total solid waste stream, 40% of that demolition waste is recycled, the majority of this being crushed concrete, see Table 7 [12].

Table 7 Quantities of building material recycled in Sydney.

<table>
<thead>
<tr>
<th>TYPE OF MATERIAL</th>
<th>QUANTITY in tonnes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>510,000</td>
</tr>
<tr>
<td>Other</td>
<td>90,000</td>
</tr>
</tbody>
</table>

Approximately 350,000 tonnes of demolition waste was recycled in South Australia in 1998 [13] and solid waste disposal in landfill has been reduced by 27% in the past eight years. This is partly due to a dramatic increase in demolition material recycling in the state.

**Quantities of Waste and Recycling Summary**

Australia wide there are quite good rates of reuse and recycling for demolished residential building materials. From 50% to 80% of materials are salvaged, and the majority of this is reused without any form of reprocessing. The rates of recovery for commercial buildings is much lower, in some places up to 69% of demolished materials, but the majority of this is reprocessed or recycled to make new materials and components. The majority of this recycled material is crushed concrete. Approximately 70-80% of demolished concrete is recovered for crushing and reuse as aggregate.
2.3 EMBODIED ENERGY

One of the more significant issues related to reusing materials, is that of embodied energy. Embodied energy is the energy required to produce or manufacture a product. This includes all or the direct energy used in the manufacturing process, and all of the indirect energy required to obtain the raw materials, transport them, and to produce the machines and infrastructure used in these production activities.

Reusing materials can greatly reduce, or avoid, the energy required for the production of new materials to replace those already in service. Reduction in energy requirements from reusing materials produces a corresponding reduction in environmental damage, particularly greenhouse gas production. Several researchers have pointed out the energy benefits of reusing materials, and the benefits of a design for disassembly or design for deconstruction strategy that would make it easier to recover materials for reuse [14] [15].

Data Quality
Embodied energy analysis in Australia is not well developed, primarily due to the lack of reliable process analysis data for building materials and components, and the lack of consensus in the matter of measurement systems [16]. While there are recent databases for embodied energy values, the validity of those values has been questioned by several researchers [17] [18] [19].

Significance
Despite these concerns there has been valuable research into the significance of embodied energy within the life cycle energy of the built environment. This research highlights the potential...
energy savings that could be made through the reuse of materials and components. Different researchers show that embodied energy can be from 30% to 50% of total life cycle energy [20] [21] [22] [23]. One of the reasons for these high percentages of embodied energy, is the low level of operational energy in Australia compared with other developed countries. This is due to the relatively mild Australian climate that results in buildings that need much less artificial heating or cooling than those in more severe climates.

These studies show that while research into reducing operational energy is still important, more research on reducing embodied energy is needed. Deconstruction for reuse and recycling is emerging as one strategy that has the potential to significantly reduce the overall embodied energy consumed by buildings.

The embodied energy significance of different parts of the building has also been investigated [24]. A study of the refurbishment of a multi story office building, has shown that the retained structural frame and floor slabs represented approximately 60% of the total embodied energy, while the removed cladding, internal walls, services, and fit-out represented approximately 40%. The potential energy saving in reusing removed items is very high. In the case study building, the removed items were replaced with new materials and components whose embodied energy represented more than half as much again as those removed.

One Australian study of embodied energy significance, using international data, has also considered the energy of refurbishment within the whole life cycle energy consumption scenario. This study highlights further the significance of energy savings to be made through reuse of materials and components by showing the comparatively large portion of total energy use that is embodied in the building fabric, see Figure 3 [25].

![Figure 3](image_url)

*Figure 3 Total life cycle energy use over the typical forty year life of an office building, showing embodied energy to be 30% of total energy use.*
Recycling Energy
There are several Australian research projects that have investigated the energy savings to be made through reuse and recycling of demolished or deconstructed building materials.

Research at Deakin University has investigated the embodied energy values of timber wall studs, steel studs, and recycled steel stud [26]. The study shows that ‘recycled steel’ studs require approximately half the embodied energy of ‘average steel’ studs, but the study also points out that the methods of assessment are not consistent enough to draw any meaningful conclusions.

Research has been conducted by the government research organisation CSIRO into the energy expenditure of recycling demolished concrete [27], which as mentioned previously has high recovery rates of up to 80% in Australia. Surprisingly this case study showed that using recycled crushed concrete as aggregate used 37% more energy than using new quarried aggregate. The greater energy requirement is primarily caused by increased transportation requirements. In the case study the concrete rubble was transported further to the crushing plant than if it had been transported to a landfill site. The study points out that:

“With all other factors remaining unchanged the recycling option becomes favourable (break-even) when the (demolished) concrete rubble has to be transported to a (landfill) tip more than 13km from the demolition site”.

This study is obviously limited to energy consumption issues and does not take into account other environmental burdens associated with the disposal of demolished concrete. Despite this, this study does show that it is not always reasonable to assume that recycling is the most environmentally beneficial option, and that a holistic life cycle assessment needs to be made.

Embodied Energy Summary
Embodied energy, and other life cycle assessment knowledge, is not well developed in Australia, but there is a growing awareness of the significance of the energy of consumption and the part that materials reuse can play in reducing energy consumption. In Australia, with its mild climate where the majority of the population lives, the issues of embodied energy are highly significant in comparison with operational energy issues. As yet though, operational energy research is far ahead of that for embodied energy.

2.4 POLICY AND LEGISULATION

Australia has three hierarchical levels of government: the Commonwealth Government, which represents the whole country, the State and Territory Governments, and the local Governments and Councils. All three levels of government have various responsibilities in the areas of environment, waste minimisation, recycling, and construction and demolition.

Table 8 Australian waste management and recycling legislation and policy [28].

<table>
<thead>
<tr>
<th>STATE/TERRITORY</th>
<th>LEGISLATION</th>
<th>POLICY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commonwealth</td>
<td>Natural Heritage Trust of Australia Act 1997</td>
<td>Waste Management Awareness Program</td>
</tr>
<tr>
<td>--------------</td>
<td>---------------------------------------------</td>
<td>-----------------------------------</td>
</tr>
<tr>
<td></td>
<td>Environmental Protection and Biodiversity Conservation Act 1999</td>
<td>Building Code of Australia</td>
</tr>
<tr>
<td>Australian Capital Territory</td>
<td>Environmental Protection Act 1997</td>
<td>No Waste by 2010 strategy</td>
</tr>
<tr>
<td></td>
<td>Development Control Code for Best Practice Waste Management in the ACT 1999</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Protection of the Environment Operations Act 1997</td>
<td>Waste Planning and Management Fund</td>
</tr>
<tr>
<td>Northern Territory</td>
<td>Waste Management and Pollution Control Act 1999</td>
<td>Waste Management and Pollution Control Strategy 1995</td>
</tr>
<tr>
<td></td>
<td>Environmental Assessment Act 1994</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Draft) Environmental Protection (Waste Reduction, Recycling and Disposal) Policy 1999</td>
<td></td>
</tr>
<tr>
<td>Tasmania</td>
<td>Environmental Management and Pollution Control Act 1994</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Land Use Planning and</td>
<td></td>
</tr>
</tbody>
</table>
Commonwealth Government

Australia is a signatory to the United Nations Agenda 21, and since 1992 has been committed to the National Strategy for Ecologically Sustainable Development.

Australia, as a member of the Australian and New Zealand Environment Conservation Council (ANZACC), is committed to achieving a target of a 50% reduction in waste going into landfill by the year 2000, based on 1990 levels. The Commonwealth Government’s primary initiative to help achieve this goal has been the Waste Management Awareness Program, which among its funding initiatives supports the WasteWise Construction Program. The construction and demolition industry has been specifically targeted for waste reduction because up to 40% of landfill waste is generated by the building industry [29].

The WasteWise Construction Program was initiated in 1995 as an agreement between five major construction companies and the Commonwealth Government, with an aim to develop best practice in waste minimisation during construction and demolition. The program achieved greatly improved rates of recycling and reuse though most attention was centred on construction rather than demolition. The first stage of the program has resulted in the publication of a guide, WasteWise Construction Program Handbook: Techniques for reducing Construction Waste, but as the title suggests this publication does not cover demolition material recycling or reuse [30].

Other Commonwealth Government initiatives include the Housing Industry Association’s Partnership Advancing The Housing Environment (PATHE) program which was launched in 1999 and which will deliver projects that aim to reduce waste, encourage recycling and enhance the housing industry’s overall environment management practices.

The Commonwealth Government will also shortly commence the program Lifecycle Assessment In Building And Construction, which will seek to promote life cycle considerations in the construction and demolition industry to improve understanding of material and building impacts.
and opportunities for reuse and recycling of building materials and components.

The Commonwealth Environment Protection Agency is responsible for many issues regarding waste management and pollution but does not directly address issues of demolition waste. It does however identify common barriers to greater waste minimisation in general, and these barriers are true for demolition waste in particular [31];

- Absence to uniform national approach to waste minimisation.
- Lack of information on the extent, types and source of waste.
- Waste management charges that are; too low to be an incentive to avoid waste, unable to provide funding for the environmental cost of waste disposal, and poorly structured.
- Insufficient private sector interest for investment in waste management technologies.

The Commonwealth Government is also responsible for the Building Code of Australia. This code is not in itself legislation, but is called up by individual state legislation. The code is one of the primary sources of building regulations that affect the design of buildings. The code however has no reference, recommendations or restrictions on the use of reused, recycled or second-hand materials, nor does it address the issues of deconstruction.

While Australia seeks to improve its rates of recycling and reuse, particularly in the construction and demolition industry, Commonwealth Government policies have been quite broad and unspecific with no particular guidance, initiatives, or legislation on the topic of building deconstruction and material reuse. In general, most controls over construction and demolition issues rest with the state, territory and local governments.

**Australian Capital Territory Government**

In 1996 the Australian Capital Territory (ACT) Government launched the *No Waste By 2010 Waste Management Strategy*. This strategy aims at elimination of all waste going to landfill by the year 2010. In the last five years significant gains in resource recovery have been made, particularly with demolition waste, which now represents 50% of total waste being recycled or reused. The new *Development Control Code for Best Practice Waste Management in the ACT*, which at present relates only to the demolition sector, is expected to guide the way to total landfill elimination, though it is too early to judge results [32].

**Legislation**

Unlike other State governments, who rely on environmental legislation to achieve waste management policy, the ACT Government relies upon building and development legislation. Amendments to the Building Act 1998 require a waste management plan be incorporated into the approval process for demolition of any building. Any application for building demolition must be accompanied by a waste management plan, which must outline the proposed reuse, recycling or disposal of materials and components.

**Market development**

The ACT Government has established the *Canberra (ACT) Resource Exchange Network*, an Internet exchange base for reusable materials and items. The ACT Government is also the
administrator of the Australian Reusable Resource Network, an Australia wide Internet exchange service where individuals and companies can list items for exchange, or requests for items they seek. Both of these networks include building materials and components. They can be found at:


**New South Wales State Government**
The New South Wales (NSW) Government introduced the Waste Minimisation and Management Act in 1995, and the Protection of the Environment Operations Act in 1997. Under these acts the government established eight regional Waste Planning and Management Boards and initiated a number of waste management programs targeted at the construction and demolition industry. These initiatives include the development of a waste exchange directory for construction and demolition materials. This directory lists businesses that transport, recycle and reuse construction and demolition materials and building components [33].

Building approval
Under the Local Government (Approvals) Regulation NSW 1993, all applications for permission to build in New South Wales must identify the reuse of second-hand materials [34].

“The specification of the building is … to state whether the materials will be new or second-hand and give particulars of any second-hand materials to be used.”

This requires the person preparing the application, usually the architect, to identify all reused and recycled materials at the time of seeking council approval. Since approval is usually sought as soon as possible, before all construction details are resolved, this requirement means that architects must attempt to predict the use of reused materials. Any changes to the reused materials specified during the project must be later processed through council as an amendment to the application. Such bureaucratic requirements are unlikely to encourage creative thinking about specifying reused materials and components.

All applications for construction and demolition work to be undertaken in NSW must also now be accompanied by a waste management plan that outlines the quantities and types of waste that will be generated and the intended means of treatment. This is the first step in legislation that will eventually set compliance levels in an effort to increase the rates of reuse of demolition materials.

**Landfill levy**
The NSW Government, like many other states, has introduced a waste levy on materials going to landfill with a view to encouraging recycling and reuse as alternatives, this levy is currently set at $17.00 per tonne.

**Grants**
The NSW Government has also provided grants to private industry, each up to $50,000 for the development of recycling and reuse technologies and practice. Projects funded to date under this scheme include [35]:

26
• Development of new methods of blending recycled brick to meet existing engineering specifications as new construction products.

• Development of an air classification process to extract lightweight contaminants such as wood, paper and plastic from residual hard waste collected at demolition sites.

• Support of the on SITE Internet site for construction and demolition waste minimisation, developed by the Centre for Design at RMIT, this Internet site includes a database of contacts for used building materials exchange.
  http://onsite.rmit.edu.au

Northern Territory Government
Although the Northern Territory Government recently implemented the *Waste Management and Pollution Control Act 1999*, no particular actions or strategies were identified for the construction and demolition industry. There are policies on waste minimisation, but no reference to construction or demolition waste.

Queensland State Government
In 1996 the Queensland State Government introduced the *Waste Management Strategy for Queensland*. This strategy identified a number of objectives with direct relevance to the construction and demolition industry, two of which address the reuse of demolished building materials:

• Objective 7.1 states that ‘where any government building is being demolished or any site redeveloped by a government agency, a waste recovery program for all useable materials will be introduced where practicable’.

• Objective 5.9 the Queensland Government is to develop material specification guidelines for the recycling of secondary aggregates.

These initiatives have not yet produced any measurable results or case studies that have been researched.

Building Approvals
The *Queensland Standard Building Law 1991*, like that of New South Wales, requires the use of any reused or recycled materials to be specified at the time of application [36].

“What specifications … stating whether the materials will be new or second-hand and, if second-hand materials are to be used, giving particulars as required by the appropriate building officer; …”

Landfill Levy
There is currently no landfill levy in Queensland.
Grants
In 1993-94 the Queensland Government initiated the *Recycling Industry Incentive Scheme* with an aim of increasing the demand and supply of recycled materials. This scheme provides grants for establishing or developing industry that utilises recycled and reused materials or produces equipment for new recycling processes [37].

**South Australian State Government**
The primary piece of waste management legislation in South Australia is *the Environment protection Act 1993* which operates in conjunction with the *Environment Protection (Waste Management) Policy 1994*. The legislation does not however have any particular references to construction and demolition waste, nor the recycling of it.

**Landfill Levy**
The South Australian landfill levy is $4.00 per tonne.

**Tasmanian State Government**
The *Environmental Management and Pollution Control Act 1994* is the primary piece of legislation dealing with waste management and recycling in Tasmania. The act sets out many objectives for waste reduction and improved recycling but has no specific requirements for the construction and demolition industry.

The Tasmanian Government has established a target of 50% solid waste reduction by the year 2005 compared with 1990 levels. To this end the government is producing a *Waste Recovery and Recycling Directory* that will list organisations involved in the reuse and recycling of materials including construction and demolition waste.

**Landfill Levy**
There is currently no landfill waste levy in Tasmania.

**Victorian State Government**
The government body, EcoRecycle Victoria, is the agency responsible for waste minimisation and recycling in Victoria. EcoRecycle Victoria is not a legislative body but attempts to achieve its goals through co-operation with local government and private industry. EcoRecycle Victoria is funding a number of activities with construction and demolition industry relevance [38]:

- a market development program for recycled and reused materials including an Internet site with recycling guidelines and information on material availability in the form of an exchange database.

- best practice education and promotion through conferences and exhibitions such as *The Business of Recycling* (June 1999).

- Government purchasing procedures including tender guidelines that address issues of, waste management, material recycling, design for disassembly, and standardisation, (discussed in section on 'Design Practice' in more detail).
Landfill levy
EcoRecycle Victoria is primarily funded by the landfill levy, which is currently set at the comparatively low rate of $3.00 per tonne.

**Western Australian State Government**
The Western Australian Government’s *Waste Reduction and Recycling Policy* of 1997 is an attempt at addressing the rates of waste disposal in that state. The policy does not however specifically address the issues of construction and demolition waste. Despite this the government has initiated a number of demolition waste reduction and recycling projects.

Grants
The Western Australian Government established a landfill levy in 1998, the funds from which have been used in the form of grants to fund a variety of industrial waste minimisation and recycling projects including [39]:

- Develop guidelines to recycle concrete and masonry aggregate for use in new concrete construction.
- Develop certified road base to Main Roads specifications from recycled demolition waste.

**Policy and Legislation Summary**
In general, Australian legislation and policy is silent on the issues of demolition and deconstruction, and demolition material recycling and reuse. There are some government programs in place that encourage or promote building material recycling and reuse but these are fairly limited:

- Commonwealth commitment to a 50% reduction in solid waste creation, with the construction and demolition industry targeted as a major contributor.
- Landfill levies in most states used to discourage waste disposal, but fees are generally set too low to encourage wide scope recycling.
- Grants for the development of new recycling and reuse technologies including construction and demolition waste, primarily concerned with recycled concrete and aggregate.
- The promotion and development of markets for reused building materials, particularly through Internet exchange databases.

**2.5 DESIGN PRACTICE**
The use of reused and recycled materials in new construction is often controlled by a variety of documents that are used both before and during the construction process. These include contracts, specifications, tender applications, building codes, and building approval applications.
These various design process documents can have a major bearing on the decision to reuse or recycle materials. In Australia there are so called ‘standard’ forms of many of these documents that may be used and adapted for individual projects. Unfortunately the standard forms of some of these documents, in their current draft, actually work to discourage the creative deconstruction of buildings and the reuse of second-hand materials.

**Contracts**

Australia has a number of widely used standard forms of building contract. These contracts are written and recommended by organisations such as the Australian Standards Association, the Royal Australian Institute of Architects, the Master Builders Association, and the Commonwealth Government. While none of the commonly used standard contracts specifically cover deconstruction or the use of reused materials, many of them do prohibit the use of reused materials through a default clause that states that materials should be new unless otherwise specified [40]. Typical examples include:

- **AS 4000 clause 29.1** “Unless otherwise provided the Contractor shall use suitable new materials..”
- **JCC clause 6.08.02** “Any material not otherwise specified shall be new.”
- **EJCDC clause 6.5** “All materials and equipment shall be of good quality and new, except as otherwise provided in the Contract Documents.”
- **AIA A201 clause 3.5.1** “The Contractor warrants ... that materials and equipment furnished under the Contract will be of good quality and new unless otherwise required or permitted by the Contract Documents, …”
- **C21 clause 53.2** “Where the nature of materials is not specified in the Contract, new materials are to be used unless the Principal agrees in writing to the use of recycled materials of equivalent standard.”
- **PC-1 clause 9.1** “The Contractor must in carrying out the Contractor’s Activities ... use materials which ... if not fully described in the Contract, are new ... and of merchantable quality …”

The effect of these default clauses is to require the person preparing the contract documents, usually the architect, to specifically state which items are to be of reused or recycled materials. In large projects this task is quite onerous, and any changes to the specifying of reused materials during the project will require the issue of notifications to the contractor and the processing of paperwork. This all has the risk of encouraging the architect to simply leave the matter alone and let the default clause take effect.

Although these contracts represent a large portion of the standard contracts used in Australia, there are some standard contracts that do not default to the use of new materials. These include SBW-2, UAV, JCT-80, and ICE.
Specifications
There are several forms of standard specification used in Australia, the most widely used is perhaps Natspec. This family of standard specifications does make reference to demolition, and provides for a ‘salvaged items disposal schedule’ and a ‘re-used items schedule’ that can be used to list any demolished items or materials that are to be reincorporated into the works.

In new construction work, Natspec does not make any default requirements for the use of ‘new’ materials, but also offers no guidance for the specifying of reused or recycled materials.

Tender Guidelines
EcoRecycle Victoria provides guidance for waste minimisation in construction and demolition including Tender Guidelines for Construction and Demolition Projects. These guidelines are intended for inclusion in general tender guidelines for construction and demolition projects. They require tender applicants to submit information on a variety of topics, generally in the form of proposals for how the tenderer will deal with certain issues, including [41]:

- Integrated waste minimisation
- Waste avoidance
- Building for disassembly
- Use of recycled and recyclable materials
- Deconstruction

These tender guidelines are intended to allow clients and architects to select a contractor who will be in sympathy with client aims regarding waste reduction and recycling.

Building Code
The Building Code of Australia is one of the main legislative instruments covering the design and construction of buildings. It consists of recommendations and minimum standards for a variety of structural, and health and safety issues. It makes no requirements or restrictions on deconstruction, nor the use of reused or recycled materials or components (see also ‘Policy and Legislation’).

Building Approvals
Some state government building regulations require that an application for building approval includes a specification of the building design that states whether any reused or recycled materials are to be used (see also individual state sections in ‘Policy and Legislation’).

Design Practice Summary
Many of the standard documents and mechanisms of design control and realisation work to encourage the use of new materials rather than reused materials. Most specifications, contracts, and materials standards are based on the use of new materials with the idea that new is better. Some are silent on the issue, but none, other than the EcoRecycle Victoria tender guidelines, actively promote the use of reused materials over new.
2.6 DEMOLITION METHODS

The most common method of demolition, particularly of commercial and industrial buildings, is a stage by stage removal of the building’s fittings and fixtures, then the demolition of the building proper using large plant such as bulldozers, cranes, and excavators [42]. There is only limited explosive demolition conducted. As discussed elsewhere in this report the demolition of residential buildings is often conducted by manual labour to more successfully recover large amounts of materials.

The Australian Standard for demolition is AS 2601-1991 The Demolition of Structures. This standard allows for both destructive demolition, and deconstruction for the recovery of reusable materials and components. The standard requires the preparation of a demolition work plan for approval by the local government authority, which is to include description of the handling and disposal methods to be employed [43].

2.7 INITIATIVES IN RECYCLED MATERIALS

As discussed, high levels of residential material recycling occur in Australia. Up to 80% of all residential deconstructed materials and components can, and are, reused or recycled.

In Australia up to 70-80% of demolished concrete is crushed for reuse as aggregate. The majority of this is used for new road base aggregate. Recent increases in the rates of concrete crushing have altered the economic patterns of waste disposal. A few years ago concrete recyclers charged to remove demolished concrete, now competition is such that they remove it for free.

Demolished concrete is broken up using mechanical machinery and the reinforcing steel is removed for recycling. The concrete is then further crushed and the remaining steel is electromagnetically removed before any other contaminants are removed by hand. In the mid 1990’s crushed concrete sold as aggregate for up to $15 per tonne [44].

The Commonwealth Government research organisation, CSIRO, and Alex Fraser Recyclers Pty Ltd are currently conducting research into the use of crushed concrete as an aggregate for use in new concrete. This research includes trials of premix concrete made with 100% recycled concrete aggregate. Trials are currently for use in non-structural applications such as paths and driveways [45]. While there are definite environmental and economic benefits from recycling concrete in this way, the energy requirements of such a process have come under scrutiny as discussed elsewhere in “Embodied Energy”.

2.8 INITIATIVES IN DECONSTRUCTION
For forty thousand years Australians have lived with temporary structures that have reused materials in primitive dwellings. Even in the last two hundred years of European settlement there has been considerable activity in the area of reuse, and in particular, design for disassembly.

**Portable Cottages**

In 1788 when the first European settlers arrived in Sydney Cove in Australia, Governor Phillip brought with him from England a prefabricated portable house with a structural frame of timber and a roof and walls of painted cloth [46]. This house was designed to be deconstructed for relocation. In the following decades many similar designs for portable cottages were seen in Australia. The success of this technology was in part due to the shortage of suitable material for building and the shortage of skilled labour.

Among the most successful manufacturers of these cottages was John Manning of London. Manning’s cottages, which came in standard designs of from one to four rooms, were constructed of a bolted timber frame and interchangeable timber panels [47]. A newspaper advertisement of 1837 described the Manning portable cottage as being:

‘manufactured on the most simple and approved principles . . . complete for habitation in a few hours of landing. They may be taken to pieces and removed as often as the convenience of the settler may require’ [48].

Timber was a popular choice for construction, but it was not the only material used in these prefabricated buildings. With the development of corrugated sheet iron in the early 1820’s and the patenting of hot-dip galvanising in 1837, portable iron cottages became a common way of dealing with the building shortage in Australia. The sheet metal’s light weight made it ideal for transport and for re-use, and it was soon used, and re-used, for everything from cottages to churches and from warehouses to hotels [49].

**Timber Cottages**

The development in the later part of the Nineteenth Century of modern timber framing techniques saw the proliferation of standard timber sizes for structural members and for wall and floor linings. Such developments eventually led to the kit house, a more permanent version of the portable cottage. The standardisation of materials and components allowed the houses to be easily adapted, extended or relocated.

**Contemporary Houses**

The continuing high rates of material and component re-use in the residential sector (as discussed earlier in ‘Quantities of Waste and recycling’) are perhaps best illustrated through two recent developments in residential construction. These are the use of relocated houses and parts of houses in projects by architects, and the emergence of new systems of prefabricated buildings that have the added advantage of being deconstructable for reuse or recycling.

**Relocation**

The relocation of timber houses has traditionally been the realm of speculative builders developing subdivided suburban blocks. Architects who have explored the greater possibilities
from this activity are now adopting this common practice. In these projects, the halves or sections of relocated houses are re-joined in a new geometry that makes better use of environmental aspects such as solar access, cross ventilation, and general aspect [50]. In this way whole sections of houses are reused in a relatively intact form, Figures 4 and 5.

In these examples the nature of the material (timber), the joining techniques, and the standardisation of members, has allowed for large-scale reuse of building elements in a creative manner. This relocation of timber houses continues a strong history of building alteration and refurbishment for re-use.

Figure 4  House during relocation – house has been relocated in two halves that are set apart to create new relationship (by Jeremy Salmon Architect).

Figure 5  Floor plan of house relocated in two halves set apart (by Jeremy Salmon Architect).
Prefabrication
Prefabricated housing has not reached high levels in Australia where most new housing is in the form of detached houses built on site by major ‘project’ building companies. Some companies are however attempting to break into the ‘project home’ dominated market with prefabricated low-cost building systems. These companies are using various technologies, sometimes patented, to develop modular systems that allow not only assembly, but also future disassembly. Such disassembly is presented as an advantage for future adaptability of the house should the family structure alter. While the re-use of elements is limited to the same building or other buildings utilising the system, the environmental and waste management benefits of this practice have been identified [51] [52].

Non-residential Examples
Although housing is the major area of deconstruction activity there are some other interesting examples and initiatives. The much-publicised ‘Green’ Olympics of Sydney 2000 have sadly failed to deliver much environmental sustainability. Deconstruction and reuse has been limited to the reuse of crushed concrete from demolished buildings on the site and relocation of rock and soil from excavations. The principle stadium for the games is believed to be the first major Australian building to have undergone a full life cycle assessment [53]. The building does not however utilise recycled or reused materials though 76% of the structure is capable of being recycled in the future.

The Olympic Games site has also provided the opportunity for a relocatable viewing platform. A 200m² platform was designed to allow for relocation to different parts of the site to best allow viewing of the various construction projects. Features of the structure that allow disassembly include; steel and timber construction as best to reduce size and load, paired structural members that support edges of roofs during disassembly, and stainless steel dowel connections [54].

The World Exposition of 1988 in Brisbane saw the construction of numerous temporary buildings that were designed to be dismantled after the event and relocated for reuse. The prefabricated panel system and bolted external structural frame have allowed the buildings to be easily disassembled, relocated, and converted for use as commercial and industrial buildings.

There are other deconstruction projects, though most, such as remote research stations and the relocatable viewing platform in the Royal Botanical Gardens in Tasmania [55], are isolated projects that are not accompanied by any research or greater intent other than fulfilling their own brief.

Initiatives in Deconstruction Summary
While these non-residential examples do illustrate the potential of deconstruction as a strategy for both economic and environmental benefit, they are isolated incidents. The vast majority of deconstruction activity in Australia is in the residential sector. Australia has a strong history of building material reuse that is in part due to;

• the construction technology and materials of older detached houses
the history of the pattern of European settlement
the current popularity of ‘historic character’ houses

2.9 RESEARCH IN DESIGN FOR DECONSTRUCTION

Design for deconstruction has a notable history in Australia, but an understanding of this as a strategy for environmental benefit is only just developing. A few authors and researchers have highlighted the environmental benefits of such a strategy and conducted some research into this area.

Research
In research led by an Australian academic, a survey of worldwide designers and construction professionals was used to develop a number of guidelines for designing for building systems replacement [56]. The resultant guidelines provide design assistance for designing for future disassembly of building services components. Though the research provided a large number of guidelines, many of them are very specific to certain building systems and services and have no apparent general relevance to disassembly issues.

Other authors have discussed deconstruction issues in a more general way and presented broad guidelines and policies for designing for deconstruction [57] [58]. These studies point out the environmental benefits of deconstruction in a generic sense.

Guidelines
A more comprehensive study of design for disassembly guidelines is currently being conducted at Queensland University of Technology [59]. This study has analysed disassembly guidelines from industrial design practice, and guidelines from architectural technology, to develop a list of architectural guidelines to assist designers in creating a building that is easier to deconstruct. The guidelines can be used to assess the extent to which a building, or building design, can be deconstructed for material recovery. The guidelines will eventually be used in an assessment matrix to identify opportunities for the redesign of the building to achieve improved rates of material and component reuse. The environmental benefits of such a strategy have also been investigated in a life cycle scenario [60]. The guidelines being developed will be related to four possible scenarios of recovery (see Figure 6), which are presented as a hierarchy where reuse is preferred to reprocessing or recycling.

Strategies for Material Recycling
- Use recycled materials – increased use of recycled materials will encourage industry and governments to investigate new technologies for recycling, and to create a larger support network for future recycling and reuse
- Minimise the number of different types of materials – this will simplify the process of sorting materials on site and reduce transport to separate reprocessing plants
- Avoid hazardous or toxic materials – this will reduce the potential of contaminating materials that are being sorted for recycling and will also reduce the potential for human health risks during disassembly that may make recycling a less attractive option
• Make inseparable sub assemblies from the same material – this means that larger amounts of one material will not be contaminated by small amounts of a foreign material that can not be separated
• Avoid secondary finishes and coatings where possible – such coating may contaminate the base material and make recycling less practical, where possible use materials that provide their own suitable surface finish or use separate mechanically connected finishes (some protective coatings such as galvanising will still be desirable in some situations for other reasons)
• Provide permanent identification of material types – many materials such as plastics are not easily identified and should have some form of non removable and non contaminating identification mark to allow future sorting of materials

Figure 6 The four scenarios for materials reuse in the built environment.

Strategies for Component Reprocessing
• Minimise the number of different types of components – this will simplify the process of sorting on site and make the potential for reprocess more attractive due to the larger quantities of same or similar items
• Use a minimum number of wearing parts – this will reduce the number of parts that need to
be removed in the remanufacturing process and thereby make reprocessing more efficient

- Use mechanical connections rather than chemical ones – this will allow the easy separation of components and materials without force, and reduce contamination to materials and damage to components
- Make chemical bonds weaker than the parts being connected – if chemical bonds are used they should be weaker than the components so that the bonds will break during disassembly rather than the components, for example mortar should be significantly weaker than the bricks

**Strategies for Component Reuse**

- Use an open building system – this will allow alterations in the building layout through the relocation of components without significant construction work
- Use assembly technologies that are compatible with standard building practice – specialist technologies will make disassembly difficult to perform and may require specialist labour and equipment that makes the option of reuse less attractive
- Separate the structure from the cladding, the internal walls, and the services – to allow parallel disassembly where some parts of the building may be removed without affecting other parts
- Provide access to all parts of the building and all components – ease of access will allow ease of disassembly, if possible allow for components to be recovered from within the building without the use of specialist plant equipment
- Use components that are sized to suit the intended means of handling – allow for various possible handling options at all stages of disassembly, transport, reprocessing, and reassembly
- Provide a means of handling components during disassembly – handling during disassembly may require points of connection for lifting equipment or temporary supporting devices
- Provide realistic tolerances to allow for movement during disassembly – the disassembly process may require greater tolerances than the manufacture process or the initial assembly process
- Use a minimum number of different types of connectors – standardisation of connectors will make disassembly quicker and require fewer types of tools, even if this result in the over sizing of some connections, it will save on assembly and disassembly time
- Use a hierarchy of disassembly related to expected life span of the components – make components with a short life expectancy readily accessible and easy to disassemble, components with longer life expectancy may be less accessible or less easy to disassemble
- Provide permanent identification of component type – similar to material identification, may use electronically readable information such as barcodes to international standards

**Strategies for Building Relocation**

- Standardise the parts while allowing for an infinite variety of the whole – this will allow minor alterations to the building without major building works
- Use a standard structural grid – grid sizes should be related to the materials used such that structural spans are designed to make most efficient use of material type
- Use a minimum number of different types of components – fewer types of component
means fewer different disassembly operations that need to be known, learned or remembered – it also means more standardisation in the reassembly process which will make the option of relocation more attractive

- Use lightweight materials and components – this will make handling easier, quicker, and less costly, thereby making reuse a more attractive option
- Permanently identify point of disassembly – points of disassembly should be clearly identifiable and not be confused with other design features
- Sustain all information on the building manufacture and assembly process – measures should be taken to ensure the preservation of information such as ‘as built drawing’, information about disassembly process, material and component life expectancy, and maintenance requirements

**Research in Design for Deconstruction Summary**

The first research steps in understanding how to achieve better building deconstruction through design are being taken. Several researchers have presented strategies for designing for better deconstruction. These strategies or guidelines are presented as a starting point in thinking about design for deconstruction. As each building project is unique there can be no universal strategies that will always apply, and some of these strategies may be in direct conflict with other environmentally sustainable strategies. Like all attempts at improving our environmental performance, design for disassembly must be considered in a holistic way along with all of the environmental life cycle factors that may affect a project.

**2.10 RECOMMENDATIONS**

There are many issues regarding deconstruction in Australia that need to be reformed. The high rate of material and component reuse in the residential building sector offers a good example, but performance in the commercial and industrial building sector is poor. In general government policy is neither helpful nor encouraging, and it is still too easy to simply throw used materials and components away.

**Waste and Recycling**

As is evident in this report, there is no comprehensive understanding of current rates of building material waste or recycling and reuse. Better information on the rate of waste disposal is needed to highlight the extent of the problem and the need for more action. Similarly, more comprehensive information on the rates of recycling and reuse is required, and could be used to set benchmarks for compliance. It is not yet known if the Commonwealth Government will reach the target of a 50% reduction in waste going into landfill by the year 2000.

**Policy**

There are no effective Australia wide policies on building material and component reuse. Individual state legislation is patchy and in general does not address demolition waste directly. Since demolition waste is such a major part of the waste stream, specific policy and legislation on these matters are required, covering issues such as;
• Waste reduction
• Second-hand materials usage
• Levies and fees for waste disposal that work to encourage reuse and recycling
• Grants for research and development of reuse and recycling technologies
• Market development for reused materials and components

Design Practice
Many of the documents associated with building design, and building procurement, (specifications, contracts, applications) work directly against the encouragement of using reused materials and components. Existing documents need to be redrafted to make specification of second-hand materials easier, and to make the salvage of materials during demolition or deconstruction a more attractive option for the contractor, the client, and the designer.

Initiatives in Deconstruction
There are high rates of deconstruction and material reuse in the residential sector. The demolition of commercial buildings however does not result in such high rates of reuse. One of the possible problems is the development of suitable stable markets for these much higher quantities of materials. Some recent attempts at establishing Internet materials exchange networks have been attempted but are as yet not well supported at a commercial scale.

Other problems include the perceived economic costs associated with the time required to deconstruct rather than demolish. Experience in residential deconstruction, and research in other countries, suggests that the income from material salvage can outweigh the time costs. Research is needed to illustrate these benefits in case study building deconstruction projects in Australia.

In general, while deconstruction is practiced widely in the detached residential building sector, there is not a good understanding of it economically, or environmentally. It is also strongly reliant on the construction technology employed in those buildings. Therefore this level of reuse may not be sustainable in the decades to come when ‘modern’ buildings utilising ‘modern’ construction techniques are to be demolished or deconstructed.

Regardless, current residential practice should be used as an example to the greater construction industry of how improved levels of reuse can be achieved.

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