Contract Report

Final

Recycled products in local road construction and maintenance activities

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for WALGA

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	Reviewed
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Commercial in confidence

Executive Summary

In order to investigate the potential of using recycled products in Local Government works, with emphasis on the use of recycled products in road and path construction, the Western Australian Local Government Association applied for funding under the Strategic Waste Initiative Scheme (SWIS) to develop a Local Government policy position that will:

- Minimise waste to landfill, in particular identified ‘problem’ products, and
- Facilitate the use of recycled content, by Local Government, in construction and maintenance of footpaths, cycle paths, local roads and other appropriate infrastructure.

Local Government in WA is responsible for one hundred and twenty seven thousand, forty-nine kilometres of local roads of which 28% are sealed. Local roads make up 72% of the WA road network. The estimated cost of maintaining the Local Government road network at its current condition is four-hundred and seventy-three point seven million dollars. This figure includes expenditure on maintenance, renewal, upgrade and expansion (WALGA 2009).

The future access to gravel and other road building materials is of concern. Road building materials such as naturally occurring materials used in road pavements, but not including the bituminous road surface treatments and embankment fill material, have traditionally been regarded in WA as a low cost, readily available resource. The State Gravel Supply Steering Committee has discovered that the expansion of the road network, rapid urban and other development, competing land uses and growing community concern for the environment have combined to produce shortages of readily accessible road building material in some areas (State Gravel Supply Strategy Steering Committee 1998).

Construction and demolition (C&D) materials, including concrete, brick, tiles and asphalt contain all of the raw materials in some form used in roadbase and concrete manufacture. The report has found that these materials are relatively simple to recycle, as they only require crushing, screening and/or blending to produce a range of products suitable for use in road, drainage and path construction.

The report identifies that there are a number of inhibitors preventing Local Government using recycled C&D waste in road and foothpath construction and maintenance. These inhibitors include:

- A lack of confidence in the performance of recycled products;
- A perception that by using a non-standard product, there is a higher level of risk in pavement performance;
- A cheap supply of raw materials making recycling unprofitable;
- Concern about contaminants, including asbestos; and
- A lack of incentive to use recycled materials.

The report illustrates that recycled commingled and recycled concrete road-base is at least equivalent to virgin quarried road-base if not better. The commingled recycled road-base withstands turning traffic movements exceedingly well, and this makes it a suitable material for road rehabilitation.

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Materials that have been investigated for their appropriateness and use in road building and maintenance activities include:

- Construction and demolition (C&D) waste, including concrete, brick, tiles and asphalt can be used in roadbase, drainage aggregate and replacement aggregate in concrete manufacture.
- Glass can be used in asphalt and can be added to recycled comingled roadbase.
- Tyres can be used as crumb rubber in asphalt.
- Used oil and coolants can be used in road asphalt when blended into modified and multi-grade bitumen.
- Container and plate glass can be used as an aggregate in roads and footpaths.

The report outlines that there can be significant cost savings in the use of recycled materials rather than virgin product. This is due to low material and transport costs at the recyclers, as well as the opportunity for savings from the re-use of 'box out' materials on site.

The report illustrates that there are currently rigorous checks on material deposited at C&D recyclers to limit possible contamination. The use of products sourced from C&D waste must comply with legislation associated with asbestos management and a national industry guidelines has been produced in order to negate these risks.

For Local Governments committed to sustainable practices and policies, the use of recycled materials in road construction offers many benefits. A variety of factors that should be considered in purchasing decisions include:

- Cost of raw materials;
- Long term performance of raw materials;
- Water use and energy used to work raw materials;
- Energy used to extract the raw materials;
- Loss of habitat in producing the raw material;
- Transport costs;
- Energy used in transporting materials;
- Disposal of demolition/ box out materials;
- Transport costs for demolition/ box out materials;
- Option for back-loading road making materials.

The use of recycled materials in Local Government road construction activities offers a number of financial and environmental savings, as well as a product that performs as well, if not better, than a product made of virgin quarried material. The demand for recycled C&D waste can also have an impact on the amount of waste deposited to landfill as landfill space, particularly in developed areas, is becoming increasing difficult to find.

Recommendations

1. That the Western Australian Local Government Association develop a policy on the use of recycled products in road construction and maintenance activities.
2. That the Western Australian Local Government Association develop an education and awareness package for distribution to all Local Governments in Western Australia. This will be in the form of:
   - Workshops to disseminate examples of successful use of recycled products
   - Dissemination of the report: *Recycled concrete roadbase quality investigation: report for SWIS (Strategic waste initiative scheme)grant 4003* (Bowman & Associates, 2009), demonstrating the quality control mechanisms in place by the major C&D recyclers, and
   - Promotion of existing and future specifications for use of recycled products including:
     - Crushed glass in roadbase and asphalt
     - Recycled roadbase made from demolition materials
     - Crumb rubber asphalt, and
     - Non-structural concrete.
3. That the Western Australian Local Government Association establish a preferred supplier arrangement for the supply of recycled road building materials which would include C & D recyclers;
     - Consideration in the preferred supplier arrangement will be given to the inclusion of requirements for Quality Management Systems incorporating process control.
4. That the Western Australian Local Government Association instigate further studies to quantify the whole of life environmental footprint of roadbase and aggregates from both new and recycled products, including input energy consumption and greenhouse gas emissions at manufacture and processing, effects on habitat and sustainability of supplies. The findings will be disseminated at regional workshops.
5. That the Western Australian Local Government Association advocate to the State Government to have the landfill levy for inert materials raised to a value in line with other states, in order to allow the recycling industry to remain competitive and to generate more funds for research into diversion of waste from landfill.
6. That the Western Australian Local Government Association advocate that the State Government allows the subsidisation from the landfill levy to support future recycling initiatives for glass, tyres and oil as they arise.
7. That the Western Australian Local Government Association advocate to the State Government that requirements for waste management plans be mandatory for all large scale State and private projects involving major demolition works.
8. That the Western Australian Local Government Association include specifications for the supply of recycled materials in road construction and maintenance activities as and when appropriate specifications are developed and accepted by industry associations.
9. That the Western Australian Local Government Association promote to Industry Associations and Training Councils inclusion of specific issues

relating to the use of recycled products in road construction and maintenance activities.

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1 Introduction

The use of recycled materials in the construction and maintenance of roads has been occurring in Australia for the last 20 years with the most notable sources being:

- Construction and demolition (C&D) wastes which are predominantly concrete with proportions of brick and masonry
- Reclaimed asphalt pavement (RAP)
- Industrial slag predominantly iron and steel
- Ash and fly ash from coal burning power generating plants, and
- Rubber tyres either as crumbed rubber additives to new asphalt or as retaining structures.

Recently recycling of container glass into granular products has gained acceptance, with all states adopting glass container recycling to varying degrees, either for reprocessing or recycling into other products. In addition, a range of stabilised materials and asphalt are being produced from recycled C&D aggregates based upon bitumen emulsion, hot asphalt, and cementitious binders.

Whilst the state of the recycling industry is well developed in South Australia, Victoria and New South Wales, in Western Australia, it is still developing. As a result of gaining a Strategic Waste Initiative Scheme (SWIS) grant, the Western Australian Local Government Association (WALGA) appointed ARRB Group to provide this report on the 'state of the industry and its acceptance in the market' and assist in development of a Local Government policy position that will:

- Minimise waste to landfill, in particular identified 'problem' products, and
- Facilitate the use of recycled content, by Local Government, in construction and maintenance of footpaths, cycle paths, local roads and other appropriate infrastructure.

In developing the policy position, this report has:

- Provided a background to state, national and international practices and suggestions that could decrease the volume of waste sent to landfill
- Documented the nature of the recycling industry in WA and the legislative authorities under which it operates
- Identified the drivers for Local Government to use recycled materials in roads, paths and other appropriate infrastructure, such as the WA State Government Towards Zero Waste Vision and Local Government Strategic Waste Management Plans, and
- Identified the inhibitors to using recycled products in road and path activities by Federal, State and Local Governments and industry.

2 Current WA legislation, landfill and recycling operations

2.1 Current WA legislation

Legislation relevant to the disposal of waste in WA is contained in three Acts:

- *Waste Avoidance and Resource Recovery Act 2007*
- *Waste Avoidance and Resource Recovery Levy Act 2007, and*

- *Environmental Protection Act 1986.*

Waste disposal may also be indirectly affected by other Acts including:

- *Occupational Safety and Health Act 1984*
- *Health Act 1911*
- *Litter Act 1974,* and
- *Contaminated Sites Act 2003.*

The objective of the *Waste Avoidance and Resource Recovery Act 2007* is covered in Section 5 which states:

5. Objects of this Act

(1) The primary objects of this Act are to contribute to sustainability, and the protection of human health and the environment, in Western Australia and the move towards a waste-free society by:

(a) promoting the most efficient use of resources, including resource recovery and waste avoidance

(b) reducing environmental harm, including pollution through waste,

(c) the consideration of resource management options

against the following hierarchy:

(i) avoidance of unnecessary resource consumption;

(ii) resource recovery (including reuse, reprocessing, recycling and energy recovery), and

(iii) disposal.

(2) The principles set out in the Environmental Protection Act section 4A apply in relation to the objects of this Act.

Section 4A of the *Environmental Protection Act 1986* states:

4A. Object and principles of the Act

The object of this Act is to protect the environment of the state, having regard to the following five principles:

1. *The precautionary principle*
Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. In the application of the precautionary principle, decisions should be guided by:

(a) careful evaluation to avoid, where practicable, serious or irreversible damage to the environment, and

(b) an assessment of the risk-weighted consequences of various options.

2. *The principle of intergenerational equity*
The present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations.

3. *The principle of the conservation of biological diversity and ecological integrity*
Conservation of biological diversity and ecological integrity should be a fundamental consideration.

4. *Principles relating to improved valuation, pricing and incentive mechanisms*
(1) Environmental factors should be included in the valuation of assets and services.

(2) The polluter pays principle — those who generate pollution and waste should bear the cost of containment, avoidance or abatement.

(3) The users of goods and services should pay prices based on the full life-cycle costs of providing goods and services, including the use of natural resources and assets and the ultimate disposal of any wastes.

(4) Environmental goals, having been established, should be pursued in the most cost effective way, by establishing incentive structures, including market mechanisms, which enable those best placed to maximise benefits and/or minimise costs to develop their own solutions and responses to environmental problems.

5. *The principle of waste minimisation*
All reasonable and practicable measures should be taken to minimise the generation of waste and its discharge into the environment.

Landfill is the predominant method of waste disposal in Western Australia, although alternative waste technology facilities for dealing with putrescible waste have been developed. Landfill space, particularly in developed areas, is becoming increasingly difficult to find. Landfill management techniques have improved and larger landfill sites capture gas generated by the biological breakdown of putrescible waste. This is recognised as a form of renewable energy and generates Renewable Energy Credits (REC).

The *Environmental Protection Act (1986)*, has recommended a whole-of-life approach to resource conservation and recycling, which has been strengthened by the *Waste Avoidance and Resource Recovery Act (2007)*. This legislation enshrines the waste hierarchy as an approach to waste management

Under the EP Act, waste is defined as:

- Any substance that is discarded, emitted or deposited in the environment in such volume, constituency or manner as to cause an alteration in the environment
- Any discarded, rejected, unwanted, surplus or abandoned substance
- Any otherwise discarded, rejected, unwanted, surplus or abandoned substance intended for sale or for recycling, reprocessing, recovery, or purification by a separate operation from that which produced the substance, and
- Any substance described in regulations under the *Environmental Protection Act 1986* as waste.

Using this definition, recyclable materials are classed as waste.

Waste, as defined in the *Waste Avoidance and Resource Recovery Act 2007* includes matter:

(a) whether liquid, solid, gaseous or radioactive and whether useful or useless, which is discharged into the environment, or

(b) prescribed by the regulations to be waste.

Wastes are commonly grouped according to their source. The common waste classifications based on the source of the waste are defined by the Department of Environment *Landfill Waste Classification and Waste Definitions* (1996) as follows:

- Municipal solid waste (MSW) – waste, consisting of:
  - Household domestic waste that is set aside for kerb-side collection or delivered by the householder directly to the waste facility; or
  - Other types of domestic waste (e.g. domestic clean-up, furniture and residential garden waste); or
  - Local Government generated waste (e.g. waste from street sweeping, litter bins and parks); or
  - Commercial waste generated from food preparation premises, supermarkets etc;
- Commercial and office waste – This is a diverse waste stream, generated from commercial and industrial operations, including, but not limited to processing and manufacturing industries, service sector, and the trade and transport and distribution sectors, primary production and mining, and
- Construction and demolition waste –The types of wastes generated from C&D include the removal of unsuitable materials from building sites prior to construction as well as waste from the construction process. Soil that is either contaminated or unsuitable for building on is also a large part of the waste going to landfill from this stream.

2.1.1 Landfill levy and gate charge considerations

Materials delivered to any landfill site attract a charge, and this charge is made up of a gate fee and a landfill levy. The gate charge is to cover the operational costs of the landfill. All landfills are either licensed or regulated by the Department of Environment and Conservation, and the holder of a licence in respect of premises is liable to pay the amount of any levy imposed for waste received at the licensed premises. The levy is paid to the State Government. The Levy is charged on all waste generated or land filled in the Perth Metropolitan area.

The Levy amount was originally set by the *Environmental Protection Regulations 1987* in Section 27. In 2007 with the advent of the *Waste Avoidance and Resource Recovery Levy (WARRL) Act 2007,* the Levy was then charged under the *Waste Avoidance and Resource Recovery Levy Regulations 2008.* These Regulations were adopted on 1 July 2008, and prescribe the operation and amount of the landfill levy.

The levy structure originally set under the *Environmental Protection Regulations 1987* covers three categories of landfill operations:

- Category 63 landfill sites (inert), and
- Category 64 and 65 landfill sites (putrescible).

Under the WARRL Act Regulations, the Levy was set as follows:

- Category 63: $3.00/m^3 based on volume of compacted fill until 1 July 2008
- Categories 64 and 65: $7.00/t for 92% of delivered weight from 1 July 2008 to 1 July 2009
  $8.00/t for 92% of delivered weight from 1 July 2009 to 30 June 2010
  $9.00/t for 92% of delivered weight after 1 July 2010.

The basis of the 92% value of delivered weight is to allow an 8% margin for inert cover material as this is considered a necessary import for landfill operations.

Should inert material suitable for category 63 landfill be delivered to a higher category landfill, the higher rates are applied. Gate charges are determined by market forces and an operator will charge whatever fee possible to balance between landfill life and profit.

In the 2009/10 State budget, it was announced that the levy would increase to $28.00/tonne for putrescible wastes and $12.00/m^3 for inert wastes. At the time of going to print, these regulations had not been tabled.

The landfill levy applied across Australia varies from state to state. The following information details the Levy rate in various states. Levy rates for prescribed wastes (those materials containing some degree of hazardous contamination) are omitted, as these are outside the scope of this report.

The Landfill Levy described below may not give the total picture, as the gate charge at landfill in some states may be higher than others, and actual gate charges between landfill sites will also vary within states. A comparison of landfill levies obtained from various State Government websites (2009) is shown in Table 2.1.

Comparatively, WA has the lowest levy, particularly for inert waste (construction and demolition materials). With a compacted density of inert material likely to be between 1.5 and 2.0t/m^3, it indicates that the current levy is around $1.70/t. Even with the increase proposed in the 2009/10 budget, the effective rate will only rise to approximately $6.80/t.

Table 2.1: Comparison of Australian state and territory landfill levies

State	Metropolitan		Rural	
	Source of waste			
	Putrescible	Inert	Putrescible	Inert
Western Australia	$6.00/t	$3.00/m^3	nil	nil
Victoria	$9.00/t	$15.00/t	$7.00/t	$13.00/t
New South Wales	$46.70/t	$46.70/t	$40.00/t	$40.00/t
South Australia	$23.40/t	$23.40/t	$11.70/t	$11.70/t
Queensland	No levy currently applied (a state-wide levy of $20.00/t is before parliament)			
Tasmania	No levy applied			
Northern Territory	No levy applied			
Aust Capital Territory	No levy applied			

2.1.2 Western Australian issues affecting recycling

Due to population distribution, most waste material is generated in the Perth and Peel regions. Consequently most recycling material is also generated in these areas. There are significant efforts being made to recycle materials in other regions of WA, for example the Pilbara and South West.

The general issues for recycling in WA include:

- Distance – to transport material from regional areas to the market
- Distance to market – the majority of material (not including organic and C&D) is transported interstate or internationally to be reprocessed
- Relatively low population – consequently volumes of recycled material sufficient to support reprocessing infrastructure may not be present
- Increasing diversity and volume of the waste stream – products generated are becoming increasingly complex (for example electronic waste) and population increase leads to more waste being generated, and
- Increasing cost to process recycling – the preceding issues increase the cost of recycling as there limited economy of scale in WA and large distances to transport material.

There are also issue unique to particular regions. The State Government has provided funds to Local Government to generate Strategic Waste Management Plans (SWMP), these plans identified some of these specific issues.

Example 1: Pilbara Regional Council SWMP

Due to large mining infrastructure and harsh conditions, used tyres are a particular problem in the Pilbara, as well as other waste streams. The Pilbara SWMP identified the following issues:

- The need to better plan for the management and development of each of the four Local Government landfill sites recreation assets
- The need to identify opportunities for the sustainable recycling and/or reuse of materials within the Pilbara Region
- The recognition that Local Government have a growing role to play in reducing the quantum of waste disposed of landfill;
- The desire by the public to have increased recycling services available in the Pilbara Region, and
- The impact of poor waste management on the Region's tourism industry.

Of particular note is the desire to establish a tyre processing/recycling facility, the reuse of glass in roadbase and paths, and the reprocessing of railway sleepers.

Example 2: Batavia Regional Organisation of Councils (BROC) SWMP
BROC is a Regional Organisation of Councils and consists of the Shires of Northampton, Chapman Valley, Irwin and the City of Geraldton-Greenough.

The BROC SWMP covers the following major areas:

- Kerbside recycling / material recovery facility
- Drop-off recycling facilities
- Landfill licence / regulations compliance
- Greater engagement of the community through education
- Greater regionalisation of waste services in the BROC, and
- Consolidation of landfills across the BROC.

Further Example

The Shire of Augusta Margaret River has invested in a glass crushing plant to recycle glass into road base.

Waste management and the minimisation of waste are of major importance to all Local Governments, and actions that will lead to conservation of landfill and reuse of resources are important throughout the state. For small population centres, the costs to establish any technologically advanced recycling system may be prohibitive due to the small scale of the operations.

Transport distances from regions to centralised recycling facilities often make recycling a cost prohibitive exercise, and variations in market forces result in cycles where a recycling operation may change form profitable to non profitable in a short time frame.

For recycling to be successful, there must be a market for the products produced, and in WA, due to the small population base, local markets are often limited. Transport to other more remote markets may make some recycled products unprofitable.

The availability of cheap raw materials makes it difficult in some cases for recycled products to compete with a new product. The absence of market based instrument to recognise externalities associated with the extraction and processing of raw materials keeps their prices artificially low.

2.1.3 Specific waste types

Historically, low landfill costs and an abundance of good quality road-making materials have been and remain major factors affecting the disposal of demolition materials in WA. In more recent times, however, as landfills have filled and closed, particularly in inner city areas, there has been a large increase in costs.

Local Government in WA is responsible for one hundred and twenty seven thousand, forty-nine kilometres of local roads of which 28% are sealed. Local roads make up 72% of the WA road network. The estimated cost of maintaining the Local Government road network at its current condition is four-hundred and seventy-three point seven million dollars. This figure includes expenditure on maintenance, renewal, upgrade and expansion (WALGA 2009).

The future access to gravel and other road building materials is also of concern. Road building materials such as naturally occurring materials used in road pavements, but not including the bituminous road surface treatments and embankment fill material, have traditionally been regarded in WA as a low cost, readily available resource. Expansion of the road network, rapid urban and other development, competing land uses and growing community concern for the environment have combined to produce shortages of readily accessible road building material in some areas (State Gravel Supply Strategy Steering Committee 1998).

State, Local Governments and some contractors in Victoria, New South Wales and South Australia have recognised the potential for using recycled construction and demolition materials in road applications. In Victoria in the early 1990s over 500,000 tonnes of recycled material was incorporated into the Western Ring Rd, similarly in SA in 2003 over 200,000 tonnes was incorporated into the Port River Expressway. Overall production of recycled products sourced from C&D wastes in Australia amounts to around 9 million tonnes per annum (Hyder 2008).

Contamination of C&D material with asbestos is an issue for this material type within which the inert recycling comply with State legislatures and the WMAA Guideline for management of asbestos contamination in material production.

Reasons deterring people from using recycled C&D have included concerns about contamination and appropriateness for use. Many of the quality issues have been resolved, through the application of rigorous quality assurance procedures.

Contractors supplying recycled demolition materials for road construction have established procedures to effectively separate undesirable foreign materials, and establishing screening procedures to reduce variability and control grading (Bowman 2009).

Concrete and clay bricks

Whilst concrete and clay bricks are a subset of the commercial and demolition stream, they deserve special consideration because there are specific recovery programs in place which focus on reuse.

Example 1: Court Yard Bricks.
Court Yard Bricks, receive, sort and resell bricks. This is a labour intensive, and consequently costly, process which is most applicable to paving bricks which are clean of adhered mortar. Reuse is a preferred option in this case as it is less energy intensive than other recycling options.

Example 2: Midland Brick
Midland Brick provides a recovery service for surplus bricks from building sites and provides drop-off centres for unwanted bricks. These bricks are sorted and those suitable for reuse are sold, and reject bricks are crushed and reprocessed.

Clay bricks may also be recycled into brick manufacture, and given the shortage of clay for the brick industry in Perth, this action is a higher value end use than in roadbase or drainage aggregate.

Container glass

In the early 1980s, a large part of the container glass stream was reused. Soft drink, beer and milk was supplied in heavy duty glass bottles that were collected by shops, milk vendors and mobile contractors and sorted and returned to the factory for washing and re-filling. The move to single-use containers has made it possible for manufacturers to use thinner, lower cost glass bottles, plastic or cardboard containers with the associated convenience for retailers and manufacturers.

Until 2002, container glass collected from kerbside recycling was processed at ACI in Canning Vale, but due to the low volume, this was discontinued. Container glass is now railed to OI South Australia. The quantity of container glass consumed in WA is estimated at 80,000 to 90,000 tonnes per year, of which approximately 20,000 tonnes is recycled (APC Environmental 2006).

Whilst accurate figures are not known, container glass consumption would likely be directly related to population, and as such, using the Australian Bureau of Statistics 2007 census, 77% of container glass is likely to be generated in the Perth/Mandurah region, 6% in the region between Waroona and Margaret River, and 1.6% in the towns of Albany, Geraldton and Kalgoorlie. The remaining 12% is spread across the other areas of the state, of which 6.5% is in the Lower South West and Wheatbelt regions excluding those major centres already mentioned.

For Local Governments practical applications for reuse of container glass include as a replacement aggregate in concrete, drainage, roadbase and asphalt applications. There are, however, energy and carbon dioxide implications when reprocessing and reusing waste glass as aggregates, as discussed in Section 3.2.3.

Pioneer Road Services has established a glass crushing plant for incorporating glass into asphalt. The supply of glass is sourced from the Southern Metropolitan Regional Council (SMRC).. Pioneer Road Services takes this glass from SMRC at no cost, but pays transport and crushing costs. It is not economically viable, but is undertaken for sustainability and environmental reasons. The plant crushes container glass to a maximum of 4 mm in size and uses this as a sand replacement in the manufacture of asphalt. The stockpile of glass, estimated at 10,000 tonnes waiting for reuse by Pioneer Road Services at the City of Canning landfill site is significant as shown in Figure 2.1.

It is estimated that 13,000 tonnes per annum of container glass is currently recovered in kerbside recycling schemes and a total of 20,000 tonnes per annum is recycled in WA (APC Environmental 2006). It is likely to be cost prohibitive and is energy inefficient to consider glass recovery from the general waste stream in areas other than the Perth/Mandurah/Bunbury and Kalgoorlie regions due to transport costs and associated fuel use. In the case of Kalgoorlie, road transport to Perth prior to loading on rail would render the recycling operation energy negative compared to manufacture of new containers.

Figure 2.1: Stockpiled glass to be recycled into asphalt

Plate glass

Plate glass is not recycled in WA. Plate glass waste is generated from demolition sites, renovations, home repairs and window manufacturers. There are no accurate figures to indicate the quantities that are disposed to landfill in each year, but based on Australian figures of 91,000 tonnes per annum, it is estimated to be around 9,000 tonnes annually. This material will be largely concentrated in the Perth to Mandurah region.

In Victoria, Visy Pty. Ltd commenced recycling of plate glass in 2002, and was at that time seeking supplies from the demolition industry. No further information could be found on this issue.

Tyres

Due to the variation in size between tyres, measurement of the number of tyres is usually expressed in equivalent passenger units (EPU). One EPU is roughly equivalent to one car tyre. In 2005, approximately 4.5 million EPUs were disposed of in WA (Howard 2006). Used tyre generation does not reflect population distribution, as it does for other materials, due to the large number and size of tyres used in the mining industry.

On an EPU basis, 44% of tyres are disposed in the Perth region and 25% in the Pilbara region. The Perth and Pilbara regions account for 69% of the EPUs generated and the South West accounts for a further 11%.

Unlike glass, tyres are easily separated, as most tyre changes are carried out by tyre dealers and can be stockpiled until a load sufficient for transport is available. Many trucks travel full to the Pilbara, and return empty, and if a recycling facility was available with the required capacity in the Perth region, tyres could be back-loaded and processed with little change to the current energy expenditure.

The Environmental Protection Regulations - 1987 prohibits the disposal of tyres in the Tyre Landfill Exclusion Zone (TLEZ) which includes the metropolitan area of Perth, unless baled and disposed into a mono fill site for later recovery. Despite the regulations only 6% of the end of life EPUs are recycled in WA currently.

Most used tyres generated in WA are disposed of to landfill. This includes the tyres generated in the metropolitan region. The TLEZ seems to have been totally ineffective in encouraging the diversion of tyres from landfill due to the number of exemptions granted to allow metropolitan landfills to receive tyres and the availability of landfill outside the TLEZ (Mathews 2005).

The TLEZ is defined in the Used Tyre Regulations. The zone covers the Perth metropolitan area and surrounding Local Government districts and includes the country towns of Beverley, Boddington, Brookton, Chittering, Gingin, Mandurah, Murray, Northam, Toodyay, Wandering and York (Mathews 2005).

Tyres may be disposed in the TLEZ only with the written permission of the CEO of the Department of Environment. Outside the TLEZ they may be disposed at a licensed landfill site or at other sites approved by the CEO of the Department. Most used tyres generated in the metropolitan region continue to be disposed of to landfill, in spite of the TLEZ, which has not been effective in encouraging the diversion of tyres from landfill. The WA Government could consider an immediate ban on the landfilling of truck tyres within the TLEZ and a ban on the transport of these tyres outside the TLEZ (Mathews 2005).

Most used passenger tyres, apart from those illegally disposed or recycled in small operations, are baled and sent to China, where they are used to manufacture rubber crumb (Source: personal communication with David Gooch – Director Tyre Waste WA, August 2009).

Baled tyres and shredded tyres encased in a geotextile can be used as lightweight fill for access roads and roads across marginal soils. Baled tyres can also be used for retaining structures on road widening operations. The use of tyres for these purposes requires changes to current WA legislation.

Whilst not a road application, crumb rubber can be used to manufacture soft paving for children's play areas. It can also be used to manufacture temporary and permanent traffic calming devices and for bases for temporary bollards.

Used oil

Under the Product Stewardship for Oil (PSO) scheme, grants have been allocated to a consortium of Wren Oil and Nationwide to establish an oil bottoms to bitumen plant in WA (Department of the Environment, Water, Heritage and the Arts 2009). Wren Oil and RNR Contracting are planning to establish a lube-to-lube oil re-refining plant at Picton in WA provided the PSO scheme continues to subsidise recycled oil at 50c per litre (ACIL Tasman 2008). There is potential for Local Government to utilise bitumen sourced from used oil bottoms in road construction, and to utilise recycled oils in road construction equipment.

2.2 Environmental considerations

2.2.1 Climate change and the construction sector

There is scientific consensus that the world's climate is changing due to increases in atmospheric concentrations of greenhouse gases. The latest Inter-Governmental Panel on Climate Change Assessment Report (2007) states that:

> Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level (CSIRO & Bureau of Meteorology 2007).

The report concludes that humans are causing this warming (mostly since the 1950s) and the changes in temperature will be larger and more rapid than any changes seen in the past.

The best estimate of annual warming over the whole of Australia by 2030 is around 1.0 ^{O}C. Later this century changes will depend on the emission scenario used (CSIRO & Bureau of Meteorology 2007). Using a moderate emissions scenario, for south-west WA projections are for up to a 3 ^{O}C rise in temperature and up to a 30% reduction in winter-spring rainfall by 2070 (Department of Climate Change 2008). Changes of this magnitude will have a significant impact on the environment and economy of urban, rural and regional Australia.

The Australian Government is proposing to introduce a Carbon Pollution Reduction Scheme in response to the threat of severe climate change. This is a 'cap and trade' where total emissions will be capped and businesses will need to hold sufficient permits to match their emissions. The principle is that permits are tradeable to ensure that carbon pollution is reduced at the lowest possible cost.

The National Greenhouse Gas and Energy Reporting System (NGERS) came into effect on 1 July 2008, which will provide the necessary data for the scheme to operate. NGERS requires all companies that use in excess of 500 Tetra joules (TJ) of energy or emitting 125,000 tonnes of carbon dioxide equivalent per annum to report annually on their emissions. Companies who are currently spending around $10 million per year on energy costs will trigger this requirement to report their emissions.

All employment sectors, including the construction industry, will face the economic implications of climate change and a Carbon Pollution Reduction Scheme. It is proposed that waste would be a covered sector under this Scheme.

The construction industry is a substantial contributor to national emissions when indirect greenhouse gas emissions are accounted for. Construction produced around 7% of total indirect emissions in 1994-95, which includes emissions from extraction, harvesting, processing and transportation of materials used in the construction industry. When direct greenhouse gas is considered, the construction sector represents only about 1.5% of the overall emissions produced in Australia. Based on 1997-98 figures, the direct greenhouse gas emissions generated by the construction industry were 4,958 (gigagrams) Gg carbon dioxide equivalent, which comprised 1.46% of national emissions totalling 339,597 Gg carbon dioxide equivalent (Trewin 2003, p. 644).

Energy and emissions accounting information relevant to the construction sector is beginning to be collected; however, there remains a heavy reliance on data collected from overseas studies. Local data collection is needed to ensure government and industry has reliable information that can help them make more sustainable material choice.

2.2.2 Process energy use and recycled materials

With increasing awareness of the potential impacts of climate change and the need to reduce greenhouse gas emissions, all industry sectors are beginning to consider the relative embodied energies (and greenhouse gas emissions) of materials they choose to use.

Various methodologies have been developed to allow a comparison of recycling paths for waste materials to be compared on an eco-efficiency basis. There are questions around what are the most eco-efficient recycling alternatives and the magnitude of any environmental gain.

There is a strong need to collect local WA data and gather evidence in relation to the relative impacts of recycling waste in terms of the following factors:

- Energy use and greenhouse gas emissions generated during reprocessing of various waste streams into aggregates and other products
- Impacts and benefits of diverting various waste streams from landfill, and
- Beneficial reuse of these materials and comparison with usage of new materials.

These considerations have already become an issue for the aggregates industry. Energy and emissions calculations from a number of studies in different countries have been reported in Section 3.1.

There are energy inputs at each life-cycle stage of construction materials from extraction and manufacture through to disposal or recovery. Resource recovery in the form of recycling will usually require further resource use to recover and reprocess waste materials for reuse in some other (or the same) application. Alternatively, the recovered waste is disposed to a landfill.

'Life-cycle thinking' in this context considers the life-cycle generated impacts of recycling versus disposal to landfill. It recognises that there are environmental and financial impacts associated with all product life-cycle stages: i.e. extracting and processing raw materials, the manufacture, transportation and distribution of these and recycling opportunities and disposal (Department of Industry, Science and Tourism NSW 1998).

The most sustainable choice will be one that reflects reduced social and environmental impacts and resource intensity, while still retaining a sound financial advantage. Environmental claims made on the basis of only one factor, for example, reduced greenhouse gas emissions can be misleading because one impact may be improved at the expense of others. For this reason, as far as possible, all social and environmental impacts need to be considered in the assessment (Lippiatt and Ahmad 2003).

Relevant elements of a comprehensive environmental assessment of recycling as an alternative to landfill could include:

Landfill benefits and effects
The benefits and effects of Landfill will vary depending on how the landfill is operated.

- Methane capture can be used to generate electricity with reduced carbon dioxide production
- Greenhouse gas emissions arising material disposal in landfill, mainly carbon dioxide and methane, contributing to climate change, more so when methane capture is not undertaken
- Air pollutants, plus some airborne toxic substances, health effects
- Leachate to soil and water, discharge of waste or site run-off to nearby receiving waters: pathways of pollutants entering soil and water are usually site specific and therefore difficult to measure e.g. proximity of landfill to receiving waters and ground water resource zones
- Amenity effects of the disposal facility – visual, noise, smell and litter – valuation based on willingness to pay or willingness to accept, and
- Attraction of vermin and birds which can transfer diseases to other locations e.g. water catchments.

Incineration benefits and effects

- Energy recovery from incineration, alternative energy production and reduction in carbon dioxide emissions
- Main emissions are local air pollutants such as oxides of nitrogen, oxides of sulphur and particulates, carbon dioxide, as well as heavy metals and dioxins, and
- Some residual waste left after incineration which is sent to landfill or could be reused e.g. bottom ash, fly ash.

Reprocessing benefits and effects

- Removal of landfill or incineration effects and resource reuse and substitution e.g. production of high quality aggregates, engineering fill material, alternative fuel sources
- Greenhouse gas emissions arising from fossil fuel use (through diesel and electricity usage), mainly carbon dioxide and methane, contributing to climate change
- Air pollutants, plus some airborne toxic substances, which can cause health effects
- Leachate to soil and water, discharge of waste or site run-off to nearby receiving waters
- Amenity effects of the recycling facility – visual, noise, smell and litter – valuation based on willingness to pay or willingness to accept

- Reduced resource consumption – substitution of new products for recycled means conserving new quarried aggregates for future generations
- Diversion of waste materials from landfill – which can mean less biodiversity, amenity and transport emissions effects
- Reduced quarrying means less amenity costs and biodiversity effects, and
- Reduced greenhouse gas emissions as recycled aggregates can have lower embodied energy in addition to reduced transport emissions where recycled materials are reused in close proximity to the site of reprocessing.

3 National and international literature

3.1 Construction and demolition waste

3.1.1 Background

Construction and demolition wastes are the most available source of potential materials able to be recycled by Local Government, particularly in larger towns or the metropolitan area where construction and demolition activity is extensive. Recycling of these materials has the potential for significant environmental benefits as well as cost savings.

The potential to use this material requires a steady supply of material, and unfortunately in WA, the current landfill levy discourages the industry to recycle, due to the cheap alternative of landfill. In addition, concerns regarding the quality of the recycled product discourage some Local Governments from using the material.

The actual consumption of raw materials in road construction in WA was not able to be determined, and will vary from year to year with major projects such as the Southern Gateway and Perth to Mandurah railway causing spikes in consumption. In 2006 some 7.6 million tonnes of sand, 4.8 million tonnes of limestone and 6.7 million tonnes of hard rock were extracted and sold in the Perth and Peel regions (Chamber of Commerce and Industry 2007). These figures are total consumption and include the housing sector.

Construction and demolition materials

Of the 32.4 million tonnes of solid waste generated in Australia in 2002–03, the Productivity Commission estimated that approximately 27% (or about 8.7 million tonnes) was municipal waste, 29% (or 9.4 million tonnes) was commercial and industrial (C&I) waste, and 42% (or 13.6 million tonnes) was construction and demolition (C&D) waste (Figure 3.1). These estimates do not include waste generated and dealt with on-site by the waste generator (Senate Standing Committee on Environment, Communications and the Arts 2008).

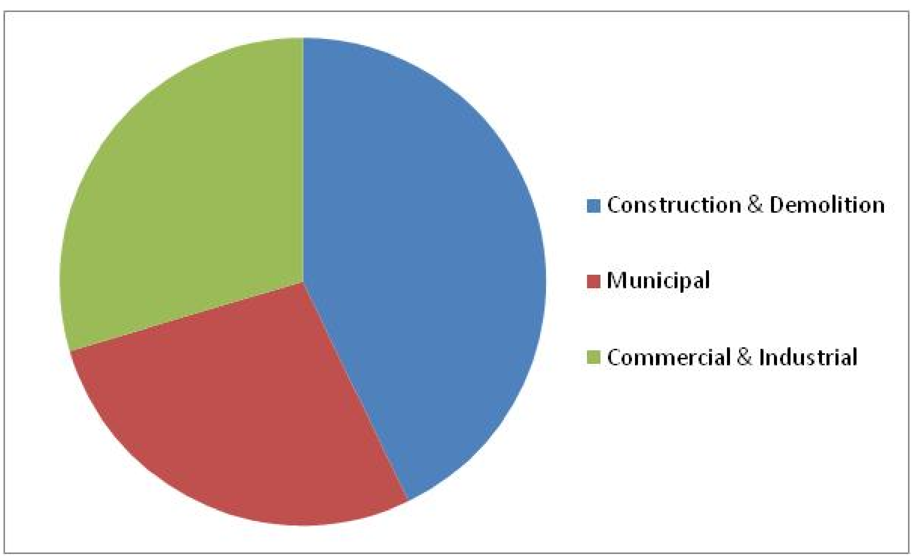


Figure 3.1: Solid waste generation in Australia by waste streams **(Senate Standing Committee on Environment, Communications and the Arts 2008).**

In Figure 3.1:

- Municipal waste comprises those materials from kerbside collections, including recycled paper, plastic, glass, metal cans, and garden waste, of which 64% is disposed to landfill
- Commercial and industrial waste comprises metals, food and garden timber (9%) and plastics, of which 50% is disposed to landfill, and
- Construction and demolition waste principally comprises timber, bricks, plaster off-cuts, concrete, rubble, steel and excavated earth, of which 35% is disposed to landfill.

The current state of the industry in some states is well developed in terms of quality control (accredited quality systems) and high volumes (e.g. South Australia, Victoria and New South Wales) and companies produce a variety of products for the infrastructure market i.e. NSW, Victoria and South Australia report that 95%, 78% and 50% respectively is recycled. By comparison, of the estimated 2.3 million tonnes of material available for recycling in WA in 2006/07, only 0.4 million tonnes or 16% were recycled and the remainder went to landfill (Cardno 2008).

Table 3.1 shows the potential application of products sourced from C&D applications. These applications are how many other states utilise recycled products from C&D activities.

Table 3.1: Typical range of applications and products sourced form C&D wastes

APPLICATIONS	PRODUCTS
Granular and stabilised pavement layers	Granular crushed rock materials
Footpaths	Bitumen and cementitious stabilised materials
Cycle ways	Aggregates for asphalt & concrete
Environmental mounds	Sand
Drainage mediums	Fill
Bedding sand	
Engineered fills	
Concrete structures	
Cold asphalt	
Hot asphalt	
Unsealed surfaces	

A photograph of a major recycling operation was included here to indicate the maturity of the industry on other mainland States and where the WA industry may head in the future. This has been edited out by WALGA.

3.1.2 WA Specifications

Main Roads WA has developed specifications for pavement engineering processes. These specifications include reference to recycled content. Specification 501.92 refers to the use of crushed recycled concrete and limits its application as a basecourse to a traffic loading of 5 x 10^6 ESA (which represents a large proportion of local roads) (Main Roads WA 2009).

Whilst Local Governments and other government agencies have developed specifications and successfully used recycled materials in local roads and other construction projects for many years. Despite the use of this material, there still remains many Local Governments which are not aware of the opportunities to use recycled materials or have been reluctant to do so in the absence of an adequate specification for Local Government activities.

The details of the MRWA specification are shown in Appendix B.

3.1.3 Energy implications of C&D recycling and reuse

The main areas of energy use and sources of greenhouse gas emissions relevant to C&D recycling and reuse relate to the following areas:

- Reprocessing energy use – usually a combination of electricity and diesel use
- Quarrying energy use – winning and processing virgin aggregates
- Transportation energy use – collection and delivery of waste feedstock to recycling facility, transportation of recycled or virgin materials to construction projects, and
- Landfilling emissions avoided – methane gas (methane) emissions generated from any organic components of recycled waste and carbon dioxide emissions arising from transporting materials to the site and operation of landfill equipment.

A recent ARRB study funded through a research and development grant provided by Zero Waste South Australia to Resourceco (a commercial and industrial waste recycling company based in Adelaide), has begun to assess the relative carbon impacts of different C&D waste disposal and recycling options.

The Study found process energy use and resulting greenhouse gas emissions from recycling aggregates to be around 3 kg/tonne. Based on a preliminary estimate, this could represent up to 60% fewer emissions than an equivalent quarry product (RMCG 2009).

Predominant fuel sources to generate electricity will vary between geographical locations (between states within Australia or between countries). The methodology used to calculate embodied energies often varies for each study. For example, the emission factors for electricity derived from coal are approximately double that of gas, and nuclear is deemed a zero carbon energy source. Within Australia, black coal has a lower emission factor than brown coal. Furthermore, some studies only include direct carbon emissions while others include both direct and indirect emissions when calculating embodied energy figures for materials.

Under the Greenhouse Gas Protocol, Scope 1 Direct Emissions are defined as those generated directly by an organisation, from sources that are owned or controlled by the company, for example, emissions from fuel consumption by mobile sources. Scope 2 Indirect Emissions are defined as those generated indirectly from use of electricity, purchased and consumed by the reporting organisation. Scope 3 Various Emissions are other, non-electricity related emissions, generated indirectly. Scope 3 emissions are a consequence of the activities of the company, but occur from sources not owned or controlled by the company. Scope 3 emissions include those coming from disposal of wastes, use of products sold, extraction and transport of purchased materials and fuels etc (Department of Climate Change 2008).

A US study of life-cycle greenhouse gas emission factors (Environmental Protection Agency USA 2003) for clay brick reuse and concrete recycling found greenhouse gas savings in the order of 30% arising from reduced process energies between virgin aggregate manufacture and recycled material. The study also considered the impact of transportation distances of materials and concluded that the use of the recycled product will result in greenhouse gas savings as long as it is transported no more than 5 km further than the quarried aggregate.

The UK Mineral Products Association (Mineral Products Association UK 2009) reports overall sector emissions averaging 6 kg carbon dioxide equivalent per tonne of quarried product. Figures range between 3.98 kg for sand and gravel, 4.02 kg for crushed rock and 26.82 kg for asphalt (process emissions only).

Average emission factors for municipal, commercial and industrial, and construction and demolition waste categories are shown in Table 3.2.

Table 3.2: Waste emission factors for total waste disposed to landfill by broad waste stream category

Waste types	Municipal solid waste	Commercial & industrial waste	Construction & demolition waste
Emission factor (kg carbon dioxide equivalent) /tonne waste)	1111	1660	250

(Department of Climate Change, 2008)

3.2 Glass

3.2.1 Background

Only about one-third of glass containers (bottles and jars) are recycled in Australia, with a goal to increase this to 55% by 2010 (Department of Territory and Municipal Services 2006). Compared to European countries where many achieve over 80% (British Glass Manufacturers Confederation 2003), these rates are quite low.

There are two environmental benefits common to all glass recycling applications:

- Glass recycling removes a significant quantity of material from the waste stream that would otherwise go to landfill. As glass is 100% recyclable (it does not wear out and can be recycled over and over again without any reduction in quality), it has no place in landfill at all (KESAB, 2008).
- In most cases recycled glass substitutes for a virgin quarried material. There are benefits associated with avoiding the environmental impacts of quarrying and processing the raw material (British Glass Manufacturers Confederation 2003).

In Australia, the glass industry pays more for cullet than it saves by using cullet in the process, therefore effectively subsidising the cullet industry. The value of the subsidy is approximately $10 million per annum. Visy Pty. Ltd. colour sorts and reprocesses container glass into cullet and provides it to OI and Amcor for reuse into glass containers (personal communication John Morris Environmental Manager, OI Asia Pacific).

The traditional role for recycled container glass has been as feedstock in the manufacture of new glass containers (closed loop recycling). The environmental benefits of using recycled glass to manufacture new containers are:

- Lower melting energy requirement for the glass
- Avoiding use of carbonate raw materials which release ‘chemical’ carbon dioxide during the glass melting process, and
- Avoiding use of soda ash, which is one of the principal glass raw materials and is very energy intensive to manufacture.

Against these benefits has to be offset the transport energy involved in the collection, transport and reprocessing of recycled glass (British Glass Manufacturers Confederation 2003).

When crushed container glass is recycled into new glass, it may make up to 100% of the content. The actual percentage depends on the quantity and quality of cullet available. In Australia today, cullet represents, on average, 30% of the batch materials (personal communication John Morris Environmental Manager, OI Asia Pacific).

In some recycling plants, cullet has to be divided into colours for recycling into new glass, due to the potential to create an imbalance between the colour mix arising from households, and demand from glass container manufacturers. In Australia, whilst glass must be very clean, and contain no contaminants (such as pyro-ceramics) the plant can handle mixed glass colours. Due to the possibility of contamination, quantities of recycled glass may not be returned, and there is a need for alternative outlets for recycled glass such as using cullet in road aggregates.

3.2.2 Recycled glass trials

As an example of an alternative use of recycled glass, trials have been undertaken by the Department of Environment and Climate Change NSW of the use of recycled glass as pipe embedment material (Department of Environment and Climate Change NSW 2007).

In another example, Shayan (2002) addressed three aspects of glass utilisation in concrete in a research program undertaken at ARRB. These aspects included coarse glass aggregate, fine glass aggregate and glass powder. The coarse and fine glass particles are used as replacement for the corresponding size ranges of natural aggregate materials, whereas the glass powder has been studied as a pozzolonic material, i.e. the same application as for silica fume or fly ash.

The data showed that there is great potential for the utilisation of waste glass in concrete in several forms, including fine aggregate, coarse aggregate and glass powder. It is considered that the latter form would provide much greater opportunities for value adding and cost recovery, as it could be used as a replacement for expensive materials such as silica fume, fly ash and cement. Any replacement of cementitious materials will bring additional environmental benefits due to reduced greenhouse gas emissions.

The study concluded that 30% glass powder could be incorporated as cement or aggregate replacement in concrete without any long-term detrimental effects. Up to 50% of both fine and coarse aggregate could also be replaced in concrete of 32 MPa strength grade with acceptable strength development properties.

3.2.3 Energy implications of different glass reuse/recycling options

Comparison of recycling container glass into glass and recycling into aggregates

The carbon dioxide emissions associated with various recycled glass applications in the UK are shown in Figure 3.2. They are compared to the ‘base’ case where glass containers are manufactured from raw materials and disposed to landfill. It is assumed that 100% recycled glass is used in each of these recycled glass applications.

Figure 3.2 shows that the base case is energy intensive and results in emissions of 843 kg carbon dioxide/tonne of glass. If recycled glass is used to manufacture the containers, the carbon dioxide emissions are reduced to 529 kg carbon dioxide/tonne for UK manufacturers and to 553 kg carbon dioxide/tonne for glass exported to be used by foreign manufacturers. In the case of aggregates the resulting carbon dioxide emissions are much less: 18 kg of carbon dioxide/tonne.

For each application, the emissions associated with recycled glass must be compared to the materials that the glass substitutes. This is shown in Figure 3.3, which indicates the carbon dioxide saving when recycled glass is used in place of the normal raw material (usually a quarried material).

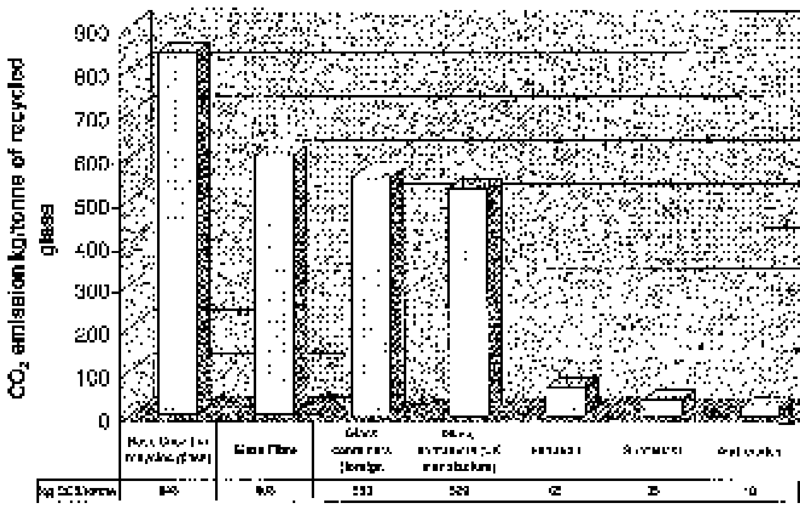


Figure 3.2: Carbon dioxide emissions for various recycled glass applications
(British Glass Manufacturers Confederation 2003, Figure 6).

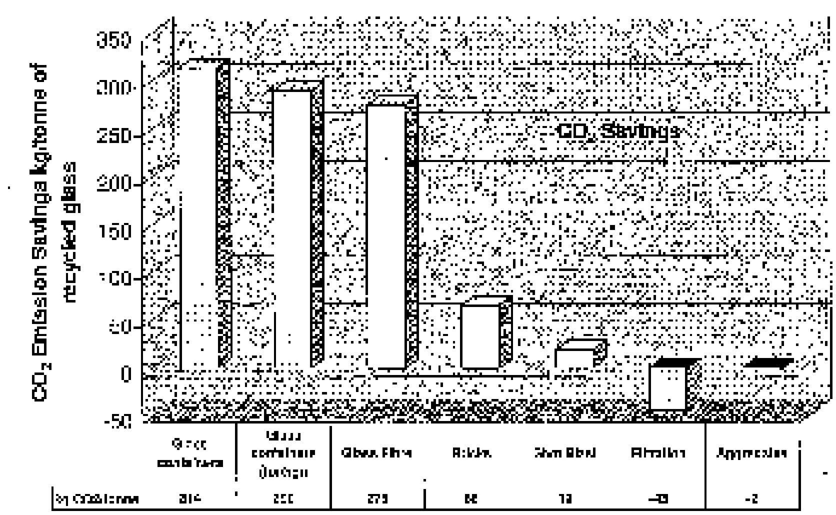


Figure 3.3: Carbon dioxide emission savings for recycled glass applications
(British Glass Manufacturers Confederation 2003, Figure 7).

The data shown in Figure 3.3 indicates that the greatest carbon dioxide emission reductions (314 kg of carbon dioxide/tonne) are achieved where recycled glass is used as a feedstock for the manufacture of new glass containers. The effect of substituting recycled glass for virgin aggregates results in a net increase in carbon dioxide emissions of 2 kg of carbon dioxide/tonne.

The large energy saving are achieved as a result of using recycled glass to produce new glass containers because:

- It requires less energy to melt recycled glass than it does to melt the constituent raw materials
- Soda ash, limestone and dolomite are three important raw materials for glass manufacture; however, during the melting process they break down and release ‘chemically bound’ carbon dioxide, and
- Soda ash is a very energy intensive material to manufacture, and its use as a raw material is avoided when recycled glass is used.

Department of Territory and Municipal Services (2006) indicate that recycling glass to glass containers requires 40% of the energy required to make glass from sand.

The low savings for aggregates are principally due to the way in which recycled glass is collected, which is on a small scale and is quite energy intensive compared to bulk haulage of virgin materials.

Using cullet in roads would be economically competitive with other materials in major metropolitan areas and their surrounds. A market for colour-mixed waste glass could significantly increase glass-collection efforts in recycling programs (Nash et al. 1995).

Cocking (2003) calculated that there are more than 50 times greater environmental benefits of recycling glass back into containers than into aggregates, even when transport is taken into account (see Table 3.3).

Table 3.3: Energy implications of container glass recycled into containers versus container glass recycled into aggregates

	Journey to container recycling	Journey to aggregates recycling
Distance (km)	330	33
Payload (tonnes)	25	25
Fuel consumption (km/l)	2.5	2.5
Energy used per tonne (litre, kWh)	5.3, 56	0.53, 5.6
Energy saving per tonne (litre, kWh)	31.9, 340	0
Energy saving (litre, kWh)	26.6, 284	-0.53, -5.6

(Based on Cocking 2003, Figure 3)

3.2.4 Drawbacks to the use of recycled glass in road construction

A issue identified by the Texas Department of Transport (2009) with the use of cullet in asphalt was problems associated with bitumen stripping in moist conditions. Recent tests have indicated that indicate there are no such problems, particularly at the low cullet to asphalt ratios that would be suggested for application in WA.

A Report by Shayan (2002) discusses in detail the chemical reaction between the silica-rich glass particles and the alkali in the pore solution of concrete, that is, the alkali–silica reaction. The research found that there is great potential for the utilisation of waste glass in concrete in several forms including fine aggregates, coarse aggregates and glass powder. It has been concluded that 30% glass powder could be incorporated as cement or aggregate replacement in concrete without any long-term detrimental effects. The use of cullet in the most common cement concrete products is not feasible due to the high levels of alkali-silica reactivity associated with it. This problem is considered to be particularly acute with fine cullet (Nash et al. 1995).

3.2.5 Summary of glass recycling issues

It is recognised that there are a number of environmental and economic benefits to recycling glass. As only about one-third of glass containers are recycled in Australia as compared to many European countries with a recycling rate of over 80%, there is a goal to increase recycling rates to 65% by 2010 (through the National Packaging Covenant).

Whilst the traditional role for recycled container glass has been to use it as feedstock in the manufacture of new containers, a number of alternative uses have emerged. These include recycling glass into construction aggregates, pipe embedment material and cement/aggregate replacement in concrete.

Research indicates that whilst the energy and carbon dioxide emissions associated with using recycled glass to manufacture aggregates are low, there do not appear to be actual energy and carbon dioxide emission savings. This is mainly due to the way in which recycled glass is collected, which is on a small scale and energy intensive compared to bulk haulage of raw material.

If the market for cullet in road construction (for example as aggregates) were to increase, however, it would become economically competitive with other materials in major metropolitan areas and surrounding vicinities, hence increasing the associated environmental benefits.

3.3 Tyres

3.3.1 Background

Australia

There are three broad market areas for waste tyres in Australia, as follows (Houghton et al. 2004):

- Waste tyre reprocessing into recovered rubber. This includes a number of target applications that use recovered rubber as an input including:
    - Road pavements as rubber modified binders, and

- Manufacture of new tyres, moulded products that typically are high volume and low technology, such as mats, domestic products (flooring, carpet underlay, etc.), and manufactured products such as athletic surfaces, acoustic floors, and playground surfaces.

- Waste to energy as tyre derived fuel (TDF). This includes the cement industry where waste tyres are used as an alternative kiln fuel, and
- Civil engineering applications, including a broad range of end uses such as retaining walls, embankments, fills and geotechnical uses such as drainage and pipes.

In 2004 sales of tyres in Australia totalled some 240,000 tonnes (including heavy vehicle and passenger vehicle tyres). Motor vehicle registration numbers increase each year, with a 12.2% increase from the start of 2003 to the end of March 2007. This continued growth in the motor vehicle market, along with increased vehicle kilometres travelled is leading to the increased consumption of tyres (Howard 2006).

Market analysis indicates that the current quantity of waste tyres in Australia is around 20.8 million equivalent passenger units (EPU) each year, representing a waste stream of approximately 197,000 tonnes per annum (Houghton et al. 2004).

In terms of current usage of waste tyres, Houghton et al. (2004) indicated the following approximate split in Australia:

- 49% of tyres are disposed to landfill
- 33% are reprocessed into recovered rubber (for a range of end uses as indicated above)
- 10% are illegally dumped
- 5% are used for waste to energy (TDF)
- 2% are exported
- 1% are used in civil construction applications, and
- A nominal % of tyres are retreaded.

This is shown in more detail in Table 3.4.

Table 3.4: Existing/immediate-term uses of waste tyres

End use	Quantity	Comments
Tyre derived fuel (TDF)	10,000 tonnes of used tyres pa estimate 1 million EPU pa 5%	Currently, only Victoria is operating a tyre-fuelled kiln. Future potential depends on tyre chip availability.
Recovered rubber (i.e. rubber crumb, shred, granules, chips and powder primarily used to make tyre derived products (TDP))	30,000 tonnes of rubber crumb pa 6.8 million EPU pa	Recent new entrants increasing capacity. Victoria and NSW are the largest re-processors. WA and Qld are smaller re-

End use	Quantity	Comments
		processors.
Road pavements (recovered rubber used)	1,000 tonnes pa estimate 210,000 EPU pa 33%	Recovered rubber in asphalt and spray seal. VIC and NSW are major users.
Civil engineering applications	200,000 EPU pa 1%	Currently small usage with significant opportunity for expansion.
Transformed rubber (i.e. some chemical or other transformation or modification process such as devulcanisation, pyrolysis or surface modification)	None	Technologies not at commercialisation stage.
Export	490,000 EPU pa 2%	International demand for casings likely to remain stable.
Landfill	10 million EPU 49% estimated	Primary objective is to redirect tyres away from landfill. The landfill estimate does not differentiate between the proportion of tyres from remote/rural areas and those from regional/city areas. The proportion of tyres directed to landfill from remote/rural areas is expected to be higher than from regional and city areas.
Illegal disposal	2 million EPU pa 10%	
Retreading	450,000 truck tyres pa 1.8 million EPU	Likely to remain stable (and possibly grow) as there is a consistent demand for truck retreads and the heavy vehicle fleet size increases.
Stockpile	20 million EPU	Numerous stockpiles throughout country mostly in regional locations.

(Adapted from Houghton et al. 2004, Table 1)

Western Australia

For tyres generated in the Perth metropolitan area, the following approximate split for waste tyres is estimated on a mass basis (Houghton et al. 2004):

- 37% are used for acceptable or approved end uses, or dumped illegally
- 34% are sent to landfill
- approximately 28% are retreaded or used for rubber recovery, and
- 1% are exported (nominal value).

This data conflicts with that supplied by URS Australia for the Department of Environment and Conservation in 2006 (Howard 2006) which estimated the following split:

- 13.8% EPU are reprocessed
- 77.8% are legally disposed (landfill export or stockpile), and
- 8.4% are illegally disposed.

The figures, however, supplied by Houghton et al. include tyres used for retreading, which cannot be considered as a waste product. In non-metropolitan areas, the number of tyres that are reused or recycled is considerably less however, there is no reliable data available (Houghton et al. 2004). It is estimated that in WA, 4.5 million EPUs are disposed of each year.

Industry is considering a variety of practices for the reuse of tyres or recovery of resources from tyres. None of these have been subject to any rigorous sustainability or life-cycle assessment and most of these methods do not would require significant financial assistance to be viable (Houghton et al. 2004).

Approximately 100,000 truck tyres per annum are retreaded in WA. Recovered rubber from the process of retreading has been used for the manufacture of secondary products and has been used in bitumen for road construction (Houghton et al. 2004). A WA company, Reclaim Industries, has developed a rubber and steel recovery system for truck and bus tyres. Approximately 42,000 truck tyres per annum (equivalent to 8% of all tyres generated in the Perth metropolitan area) are currently processed in Perth using this method. This rubber is primarily used for playground and sports pavements (Houghton et al. 2004).

Other than retreading, there is no other ongoing recovery and reuse of materials from used tyres in WA due to a range of factors. For used tyres generated outside the Perth metropolitan area (approximately 27% of the total produced in Western Australia), the large geographical distribution creates high transport costs that limit opportunities to bring the tyres to Perth for recycling or recovery. For the used tyres generated outside the Perth metropolitan area (approximately 1 million EPUs, or 9,600 tonne per annum), these issues are expected to result in higher unit costs of recovery of materials and/or energy than in many other parts of Australia (Houghton et al. 2004). There is a comparatively low cost of disposal to landfill (around $2-$6 per tyre of disposal in some landfills). It is anticipated that the Department of Environment and Conservation will ban the burial of used truck tyres, unless cut to 250 mm in the metropolitan area tyre landfill exclusion zone and the South West region of WA (Houghton et al. 2004).

Canada

The Canadian Association of Tyre Recycling Agencies (CATRA), quoted in Houghton et al. (2004) states that Canada has one of the most advanced tyre recycling schemes in the world. Tyre recycling schemes are run at the province or territory level, rather than at the national level. Nine Provinces and one Territorial Government now operate centrally coordinated scrap tyre recycling programs. The waste tyre recycling avenues is shown in Figure 3.4.

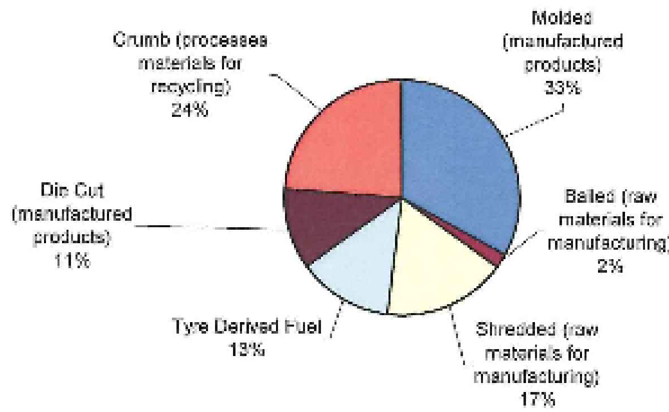


Figure 3.4: Canadian waste tyre recycling processes

USA

The US has no federally managed tyre-recycling program in place; however, all but two states have developed regulations and/or management programs for tyres. There have also been some attempts by the Federal Government to encourage recycling. In 1991 the US Congress mandated the use of ground tyre rubber in a prescribed percentage of highways that were funded by the Federal Government. Several states began testing programs; however, most states refused to comply with the mandate (Houghton et al. 2004).

The US waste tyre recycling avenues are shown in **Error! Reference source not found.**.

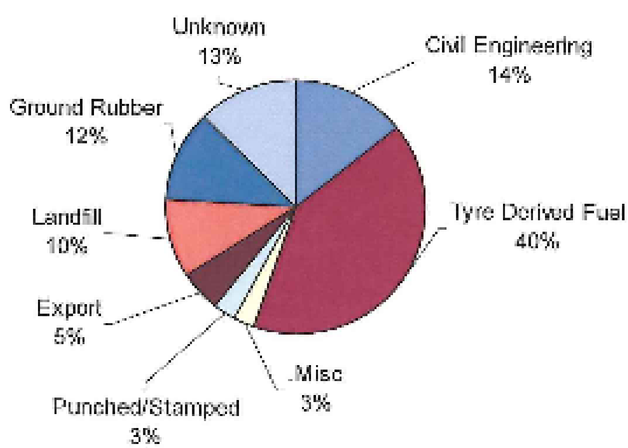


Figure 3.5: US scrap tyre utilisation, 2001

3.3.2 Energy implications/comparisons of end uses

The end use and value for used tyres will depend on the processing and market options. The disposal options may have a variety of economic and environmental variables. In order to compare the effectiveness of reuse options, a resource recovery value ranking for energy recovery use of TDF, recovered rubber and civil engineering applications is given in Table 3.5.

It should be noted, however, that each of these end uses has different investment, revenue and cost structures that make comparison difficult. In practice, the selling price is used to represent resource value, but this cost may fail to consider external costs or adverse effects that are not captured by the market (Houghton et al. 2004).

Based on Figure 3.4 and the waste management hierarchy, it is apparent that TDF is not the optimum solution to the waste tyre problem from a dollar value perspective. While other emerging markets develop, it is a viable alternative that has benefits over other options including landfill and waste incineration (Houghton et al. 2004).

Some of the advantages and disadvantages to be considered when deciding on tyre reuse options of energy recovery, recovered rubber and civil engineering applications are given in Table 3.6.

Recycled tyre rubber (crumb rubber) sells for $US200 – 400 per tonne, whereas TDF fetches one-tenth of that price. This is a clear indication that sound environmental practices and market forces are not necessarily opposites when it comes to tyre disposal (Reschner 2008).

Table 3.5: Value per EPU for selected end uses

End use	Energy equivalent	Assumptions	Value / EPU
Energy recovery (TDF) (recovery)	$80 per tonne	Assume 115 EPU per tonne	$0.70
Recovered rubber (recycling)	Value depends on particle size Assume $600 per tonne price	Assume 240 EPU per tonne of recovered rubber	$2.50
Civil engineering (recycling)		Assume 1 truck tyre (5 EPU) per m^2	$1.00

(Based on Houghton et al. 2004, Box 5).

Table 3.6: Benefits of selected end uses

End use	Advantages	Disadvantages
Energy recovery (TDF)	Reduction in nitrous oxide emissions and no solid ash	Unfavourable public image

	residue Stability of market/guaranteed market for large volume of tyres Saving of natural resources	Emission controls are expensive Low in the waste hierarchy
Recovered rubber	Limited use of natural resources High up the waste hierarchy	Expensive processing may be required (cryogenic crumb) Market currently limited
Civil engineering	Tyres need little/no processing Potential to use large volumes Variety of uses therefore not dependent on one market sector	Uncertain/variable market at present Lack of specifications limits use in larger scale applications e. g. highway construction

(Based on Hird, Griffiths and Smith 2002, Boxes 2.16, 2.17 and 2.18).

The main scrap tyre disposal methods, ranked by environmental preference are given in Table 3.7.

Table 3.7: Scrap tyre disposal methods, ranked by environmental preference

Rank	Application/Processing Method	Examples
1	Use **PRODUCT** for its originally intended purpose for as long as possible.	Design rubber compound and tire geometry for maximum durability. Keep tire properly inflated at all times to ensure maximum service life. Reuse partly worn tires. Regroove or retread tire casings.
2	Use **MATERIAL** for its originally intended purpose.	Grind scrap tires into crumb rubber, separate steel and fiber. Sell rubber as raw material.
3	Use whole scrap tires for energy recovery.	Burn whole scrap tires as fuel supplement in cement kilns.
4	Use mechanically processed tires for energy recovery.	Tire chips added to coal as fuel supplement in power plants, paper mills, cement kilns, etc.
5	Alter the chemical structure of scrap tires and use the products for energy recovery.	Pyrolysis, Supercritical Extraction.
6	Storage for possible recovery at a later time.	Monofilling.
7	Disposal without any current or future use.	Landfilling.

(Reschner 2008, Table 4).

Reschner (2008) gives the following specific energy values for selected end uses to further illustrate the hierarchy shown in Table 3.7:

- Energy needed to manufacture a tyre 32.0 kWh/kg

- Energy needed to produce tyre rubber compound 25.0 kWh/kg
- Thermal energy released when incinerating scrap tyres 9.0 kWh/kg, and
- Energy consumed in the process of grinding scrap tyres into crumb rubber (0.5 to 1.5 mm) 1.2 kWh/kg.

3.3.3 Tyre stockpiles and landfill

Stockpiles and landfilling of tyres arises for a number of reasons including:

- Low landfill charges: an increase in the disposal fee may lead to an increase in illegal dumping (Houghton et al 2004)
- Unsupportive public procurement policies: which may mean limited end markets for used tyres
- Inertia in using new products: there may be reticence to use TDR for example, and
- Misconception regarding quality of product: for example that recovered rubber from used tyres is of poorer quality than new product (URS Australia 2006).

There is currently a move towards prohibiting landfilling of whole tyres. South Australia, Tasmania, Victoria, the Perth metropolitan area and the Sydney metropolitan area have already banned this practice (Howard 2006).

Due to these regulatory requirements disposers of waste tyres must either pre-shred prior to disposal or alternatively they can dispose of whole tyres paying a higher landfill charge to cover handling, coarse shredding, and landfilling. Landfill disposal fees vary from facility to facility.

Landfill fees can be as low as $65 per tonne for shredded tyres ($0.50-0.60 per EPU) and up to $150 per tonne for whole tyres requiring shredding ($1.20 per EPU) (Howard 2006). Recent studies have highlighted disposal costs as low as $20 per tonne at landfills in NSW outside the greater Sydney region (Howard 2006). Hence shredding and its related costs are becoming a more important consideration in determining the direction of end-of-life tyres (Howard 2006).

Mandatory baling of tyres disposed to landfill has been suggested (by industry) as a mechanism that might allow tyres to be more effectively accessed in the future (URS Australia 2006). Bailing of tyres prior to disposal is likely to raise the cost of disposal which may make reprocessing activities more financially attractive Increasing education about disposal practices, options and commitment to environmental performance and responsible behaviour have probably restricted the growth in tyre stockpiles in recent years (Houghton et al. 2004).

3.3.4 Export of tyres

In using the waste hierarchy as a guide, the preferred used of a waste material for its originally intended purpose. There is an active international trade of used tyres, mostly going from industrialised to developing countries (Reschner 2008)

A tyre product market summary is given in Table 3.8. This table indicates that for engineering applications and road surfacing, the cost from recycled materials is similar to that of virgin materials. There are, however, cost savings associated with the production of TDF.

Table 3.8: Tyre product market summary

Product / end use	Description of product and process	Sale price of product	Cost to produce from virgin materials	Cost to produce from recycled materials	Comment on viability / practicality of implementation
Retaining Walls, Foundations, Paving/Roads and Erosion Control	Made using whole tyres (TC1) with/ without side wall removed	$45 – 65 per tonne	Similar to tyre derived product	Use in engineering systems is suggested to be price competitive.	Proponents of civil engineering systems that utilise used tyres claim that they are cost-effective and provide savings of between 20% and 25% over comparative systems. Unsupportive public procurement policies are considered to be a major barrier to their use
Stemming – used with explosives to force the explosive energy into the surrounding rock	TC4 granulate		$5 - 10 per tonne (price of gravel substitute)	Exceeds substitute cost	This end use market would be dependent on a fee structure operating whereby the mine would receive a fee to take whole tyres in order to cover transformation costs into TC3 or TC4 for stemming
Energy Uses – Tyre Derived Fuel	Use of tyres as a fuel substitute for fossil fuels within furnaces for cement kilns, power stations, smelters or paper mills. Can use whole tyres (TC1), shredded tyres (TC2) or tyre chip (TC3).	Estimated price of between $35 – 74 per tonne would be the highest that kilns would pay for used tyres	$74 – 88 per tonne (price of energy equivalent)	Negative if payed to avoid landfill costs	Use is dependant on community acceptance. Could consume a large proportion of end-of-life tyres. A number of barriers to the development of this industry have been identified: additional operating and capital costs; and operational difficulties can occur with tyre feeder systems.
Energy Uses – Blasting Material	An alternative blasting mixture has been developed and patented that is based on replacing the diesel in the blasting mix with granulate (TC4)	More than $500 – 600 per tonne	$1,025 per tonne – dependent on price of substitute (diesel)	$500 – 600 per tonne	Potentially this product could utilise large volumes of rubber product, but there are still key issues to be overcome to ensure product performance and acceptance.

Product / end use	Description of product and process	Sale price of product	Cost to produce from virgin materials	Cost to produce from recycled materials	Comment on viability / practicality of implementation
Road Surfacing - Spray Seal	As a polymer modified binder where a specialist product is used to bind cracked roads, as a waterproof seal on bridge decks, and on roads where additional strength is required; and in bitumen.	$400 - 600 per tonne	For use as binder and in bitumen is competitive with substitutes	Price of rubber modified bitumen - $700/ tonne	Crumb rubber asphalts are uncommon in Australia. But use in bitumen or as a polymer modified binder has accepted applications but operators dislike using this product as it exhibits a terrible odour, requires higher operating temperatures, wears the spraying equipment at a faster rate, and is more difficult to clean machinery after its use.
Flooring and Mats	Rubber crumb (TC4) provides low cost filler that can add elasticity and performance to products, such as: soft fall rubber surfacing for use in playgrounds, work areas, safety matting; marine decking; horse float and utility linings.	Product dependent	rubber mats typically are comparable in cost to rubber products that have no recycled content	$350 - 600 per tonne	Is an area that has strong adoption rates with widespread applications
Moulded Products	The TC4 products that typically are included in this end use market are: speed humps and cushions; crash barriers.	Product dependent	Similar to recycled cost	$350 - 600 per tonne	The principal substitute product in this end market is new rubber, which tends to be of higher quality, although also higher cost. There is a perception that the rubberised products are of poorer quality than new rubber.
Adhesives	Recovered rubber (TC5) can be used to produce industrial adhesives	Product dependent	Some alternatives are more expensive than TDP inputs, or have some health and safety implications that TDPs do not.	$550 - 900 per tonne for TC5	The adhesive manufacturers require crumb that is completely free of metal (due to the product liability issue of corrosion stains showing through in grouts) – so it is usually sourced from buffings.

(Howard 2006, Executive Summary table).

3.3.5 Used tyre recycling industry – triple bottom line analysis

The Department of Environment and Conservation commissioned a study to complete the business analysis of the used rubber recycling industry (derived from used tyres and rubber conveyor belts) in WA (Mathews 2005). This study was a triple bottom line (economic, social and environmental) analysis of the used tyre recycling industry. A major aim of this work was the identification of critical points at which the government will need to intervene to support and encourage the development of the industry.

The study found that there is a need for the WA State Government to be closely involved in the development of the national scheme, particularly to ensure that the state's needs relating to rural and remote tyre recycling are considered. The national scheme is likely to require considerable extra state resources for administration and enforcement (Mathews 2005).

Matthews (2005) identified that the most important market development role for state government was providing information. State Government agencies have access to a wide range of information, as well as resources to make this information available to external stakeholders. This information can take the form of reports, stockpile survey data, grants and relevant contacts.

The other very important role for government in stimulating the market is through procurement and reporting policies. Examples include encouraging the use of retreaded tyres on government vehicles and recycled rubber products in road construction and maintenance (Mathews 2005).

3.3.6 Summary of tyre recycling issues

Compared to the USA and Canada, Australia, and in particular WA, has a considerably higher percentage of used tyres disposed to landfill. This can be attributed to large geographical distribution of used tyres generation prohibiting ongoing reuse and recovery, low landfill charges, unsupportive public procurement policies, inertia in using new products and a misconception regarding quality of product, that recovered rubber from used tyres is of poorer quality than new product.

Increasing education about tyre disposal options and commitment to environmental performance has increasingly diverted tyres from landfill into three broad applications in Australia. These include:

- Waste tyre reprocessing into recovered rubber, including road pavements as rubber modified binders, manufacture of new tyres, moulded products etc. (recycling)
- Waste to energy as TDF (recovery), and
- Civil engineering applications, for example retaining walls, embankments etc. (recycling).

The waste management hierarchy rates recycling as preferable to other options (except avoidance and reuse), the market value for the above products indicate that recovered rubber (including road pavements) is the preferred option.

The cost to produce engineering materials and road surfacing from recycled rubber is similar to that of virgin materials, whilst there are cost savings associated with the production of tyre derived fuel.

It has been noted, that the waste hierarchy rates the reuse of a waste material for its originally intended purpose, such as through exporting used tyres to less industrialised countries as a preferred option.

The roles identified for government include providing information about tyre recycling options and proper tyre maintenance to extend tyre life, funding for feasibility studies and trials and market development and leading by example through procurement polities.

3.4 Used oil and coolants

A search of the Australian Bureau of Agricultural and Resource Economics website shows that between 1997 and 2007, average annual consumption of oil and greases in WA was 87 million litres and bitumen 88 million litres.

Used oil was re-refined in WA at Western Oil (later renamed Omex) in Bellevue, and the quality of the oil was equivalent to new oil. In 1970's and 80's the reprocessed oil was sold at a price less than new oil. Poor site management resulted in significant pollution of the local ground water and the site was closed in 1985.

Since then, used oil has not been reprocessed back into oil in WA. Used oil is still collected in the State by several companies, notably Wren Oil and Nationwide. Until early 2008 the service was free of charge, currently a 15 cent per litre charge has applied.

The Australian Government introduced the Product Stewardship for Oil (PSO) Program in 2001 to provide incentives to increase oil recycling in Australia. The Program, administered by the Department of Environment, Heritage, Water and the Arts (DEWHA) encourages the environmental management and re-refining of used oil, and its reuse.

The PSO applies a levy of 5.449 cents per litre on all oil sold in Australia, and uses the levy to create a fund for research and development of initiatives to process used oil into higher value products (DEWHA 2009). The levy also funds producers of higher grade products by way of a subsidy as detailed in Table 3.9.

The DEWHA Annual Report 2008 (DEWHA 2008) advises that a total of $22 million was provided from July 2000 to June 2007 in grants for:

- Used oil collection infrastructure
- Raising public awareness
- Developing technology
- Remote and indigenous projects, and
- Developing markets for used oil products.

Table 3.9: Value of subsidy for products made from used oils

Product produced	Subsidy (cents/L)

Re-refined base oil (for use as a lubricant or a hydraulic or transformer oil) that meets the prescribed criteria	50
Other re-refined base oils (for example, chain bar oil)	10
Diesel extenders that are filtered, de-watered and de-mineralised; and if combined with diesel fuels, would produce a combined fuel that is suitable for use in diesel engines	5
High grade industrial burning oils (filtered, de-watered and de-mineralised)	5
Low grade industrial burning oils (filtered and de-watered)	3
Industrial process oils and process lubricants, including hydraulic and transformer oils (re-processed or filtered, but not re-refined)	0

(DEWHA 2008)

A total of $36 million was paid as product stewardship benefits in 2007-08, with $34 million paid to recyclers for recycling used oil. This is an increase of $3.3 million in benefits for recycling compared to 2006–07 (DEWHA 2008).

The volume of oil on which benefits were paid in 2007–08 was 253 million litres, compared to 219 million litres in 2006-07. Industry estimates that 150-165 million litres of oil was being recycled annually before the Product Stewardship for Oil Program began in 2001 (DEWHA 2008).

Wren Oil and Nationwide, the two major recyclers in WA, recover oils, filters and coolant for reprocessing. The glycol from used coolants is recycled, and the used oil is predominantly used for manufacture of various grades of industrial burner oils. Wren Oil (based in Bunbury) sends tankers as far as Port Hedland and Esperance to recover used oil.

The market for burner oils in WA has decreased markedly with increased use of natural gas and closure of a major cement kiln in the goldfields. The burner oils are now shipped overseas, but the market is unpredictable, and the viability of the PSO may be affected if uses for used oil products resulting from the collection cannot be sustained. The value of various uses of reclaimed oil is shown in Table 3.10

Within WA, 66 million litres of lubricants were sold in 2005/06 and 37.2 million litres were collected during 2005/06 (Cardno 2006). When used oil is not collected there is a risk of pollution from illegal disposal into sewers, stormwater drains, soil and watercourses. A survey commissioned by the Federal Government found that one in three households have motorists who change their own vehicle oil, and nearly half of them inappropriately dispose, store or reuse the oil (Australian Academy for Technological Sciences and Engineering 2004).

Table 3.10: Costs of recycled products compared to wholesale price excluding excise

Product	Collection treatment c/litre	Process cost c/litre	Total cost c/litre	Benefit rate c/litre	Sales price typical c/litre
Lube base oil	20	40	60	50	55
Diesel fuel	15	25	40	7	40
HG burning oil	15	25	40	5	35

(Adapted from Australian Academy for Technological Sciences and Engineering 2004,Table 2.3).

European experience shows whilst the number of vehicles and kilometres travelled is increasing, recent advances in oil technology have extended considerably the time between oil changes, and that the quantity of used oil generated is decreasing (Australian Academy for Technological Sciences and Engineering 2004).

Some of the recycling processes in NSW and WA produce heavy used oil bottoms (residue) which are currently difficult to utilise or even dispose of. Uses of used oil bottoms are being explored, such as in road asphalt when blended into modified and multi-grade bitumen. DEWHA has recently called for Expressions of Interest for a National Solution for used oil bottoms.

Wren Oil and RNR Contracting have received a multi-year grant of $400,000 to establish a processing plant to recycle used oil residue into a product suitable for use in road bitumen. It was proposed to have this plant running in 2008, but due to a decision to relocate the plant from Bunbury to Fremantle, the project is now likely to be operating in 2010. Wren Oil advises that the proposal is to blend oil bottoms with bitumen at the rate of 10%. This plant then has the potential to consume approximately 8 million litres of oil bottoms per year.

3.5 Use of reclaimed materials in roadworks – other research

3.5.1 General

The Senate Standing Committee on Environment, Communications and the Arts (2008) indicates that Australians are reported to be among the highest producers of waste in the world, and that waste generation is increasing.

The impacts of waste remain a key environmental issue for Australia because of potential greenhouse and water impacts, resource conservation concerns and inappropriate disposal. It is recognised that the changing nature of the waste stream, emerging recovery, disposal and treatment technologies, and evolving community expectations all present challenges for future policy on waste management (Senate Standing Committee on Environment, Communications and the Arts 2008).

3.5.2 Greenhouse gas emissions of alternative pavement designs and rehabilitation methods

ARRB has developed a preliminary spreadsheet-based decision support tool, GHG-Pave, for assessing the materials, energy and greenhouse gas emissions embodied in different pavement designs and rehabilitation methods (McRobert et al. 2005). The main elements of GHG-Pave are shown in Figure 3.6

In this project, a range of hypothetical rehabilitation treatments and pavement designs were developed to demonstrate the potential uses for the model. The results generated indicate that there are substantial differences in greenhouse gas emissions arising from alternative rehabilitation treatments and pavement construction, with the scenarios tested showing that the lowest life-cycle emission designs have the lowest cost.

Materials with a high recycled content can be low in embodied energy depending on the amount of reprocessing and transport required and hence can reduce greenhouse gas emissions. The outputs from the model have shown that there are considerable potential greenhouse gas emission savings when substituting recycled aggregates for new materials in asphalt resurfacing projects, depending on the proximity of the worksite to a source of recycled material. The transport distance between the source of waste material and the roadwork site (and any places visited in between, for example for reprocessing) need to be taken into consideration. Table 3.11 shows the results of a comparison of three alternative rehabilitation treatments for a hypothetical rural highway. It should be noted that according to this model, a 24% reduction in greenhouse gas emissions can be achieved by substituting recycled aggregates for new materials.

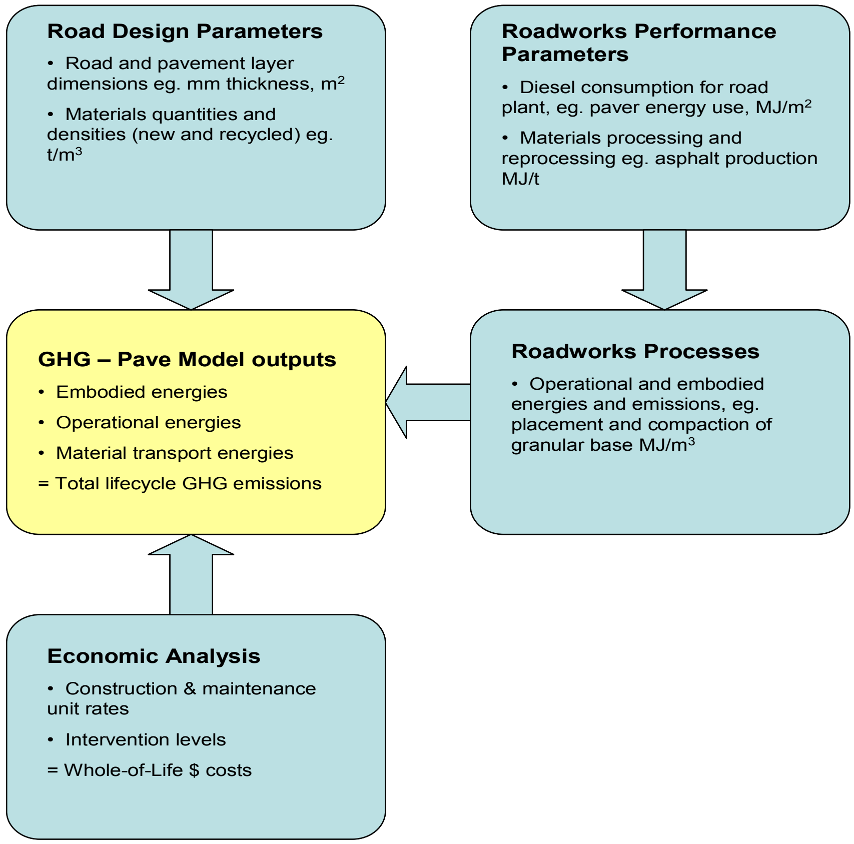


Figure 3.6: Data inputs to preliminary life cost analysis road pavement model

(McRobert et al. 2005).

Table 3.11: Model outputs: rehabilitation alternatives

Assumed road dimensions: Pavement width: 7 m sprayed seal (2 x 3.5 m traffic lanes), 6 m shoulder (2 x 1.5 m sealed shoulder plus 2 x 1.5 m unsealed), construction width:13.6 m basecourse (stepped out 300 mm either side) 20 year design life .				
Case study One: Rehabilitation treatments – rural highway showing cracking and signs of minor structural failure	**t CO_2-e per km**	**GJ energy per km**	**New aggregates t/km**	**Comments**
1. Resurface (100 mm)				24% reduction in GHG by substituting new with recycled aggregates
- new	37	397	3233	
- 50% recycled aggregates	28	318	1699	
2. Stabilisation (350 mm)				78% reduction in GHG by substituting slag for
- bitumen/cement binder	225	1683	105	

- slag/lime binder	50	416	105	cement binder
3. Thin asphalt (25 mm) & geofabric				15% GHG reduction by using RAP in new asphalt wearing course.
- new asphalt	26	388	546	
- 20% RAP	22	325	437	

(McRobert et al. 2005).

3.5.3 Technologies for resource management – recycling case studies

McRobert et al. (2000) assessed the opportunities for using recycled materials in the proposed Port River Expressway project at Gillman (a low-lying coastal floodplain prone to subsidence) and the Portrush Rd. upgrade project in South Australia. The study reviewed materials sources, uses and their characterisation in terms of potential contaminants.

A framework for assessing the potential environmental risks of placing recycled aggregates in a road formation was developed e.g. risk of contaminants from the roadbase entering the environment via ground water.

The overall project objective was to provide information for use by Transport SA officers which would lead to wider usage of waste materials and reduce their reliance on new materials. This would reduce the consumption of natural aggregates and the environmental impacts arising from accessing raw materials and the disposal of waste materials to landfill.

3.5.4 Use of recycled materials in road building – stakeholder consultations

Koszelak and McRobert (2005) gives a detailed account of individual in-person consultations undertaken with a number of stakeholders (including maintenance contractors, Local Government, Main Roads WA, recycling industry and Department of Environment and Conservation), with regards to the key factors affecting recycling rates in southwest WA. Specific roles of different agencies have been identified in WA, for example, areas that Main Roads WA can influence, and aspects of a project which fall under the jurisdiction of another department. Different recycling options were classified as either immediate potential, medium-term potential or long-range potential.

In some cases, different opportunities may be constrained by a number of barriers or constraints – these were identified. Actions were recommended for each of the immediate and medium-term activities that can be initiated by Main Roads WA, for example data collection, ongoing discussions with other stakeholders, materials research.

3.6 Potential uses for recycled materials in Local Government

3.6.1 Construction and demolition materials

Construction and demolition materials, including concrete, brick, tiles and asphalt contain all of the raw materials in some form used in roadbase and concrete manufacture. These materials are relatively simple to recycle, as they only require crushing, screening and/or blending to produce a range of products suitable for use in road, drainage and path construction.

There are at least three recycling operations in the Perth region that process demolition materials and convert them into roadbase or single size aggregates. These products may be commingled, that is a mixture of concrete, brick, tiles and asphalt, or separated material products such as concrete or brick.

Various materials have different uses: Crushed brick is often used as a ground cover in landscaping, but may also be used as drainage aggregate; crushed concrete may be used as a roadbase, drainage aggregate or as replacement aggregate in concrete manufacture; crushed asphalt obtained from profiling of existing roads (reclaimed asphalt pavement – RAP) may be used for hard stands, as the bitumen does tend to soften in hot weather and produces a reasonably stable hard stand suitable for occasional traffic. Crushed asphalt may also be used as an aggregate in asphalt. This is the highest end use value, as it makes optimum use of the bitumen on the aggregate surface, allowing lesser quantities of new bitumen to be used. Recycling asphalt this way is limited in the proportion added to the mix, as the material (RAP) does result in increased emissions from the plant as the aggregate is heated, and is not suited to all asphalt plants.

Commingled materials may also be used for roadbase, aggregate replacement in concrete and drainage aggregate. Main Roads WA (Specification 501) includes a specification for recycled concrete roadbase, and provided that a recycled product meets that specification, it should be accepted for use as a roadbase material.

3.6.2 The Welshpool Road project

The City of Canning has undertaken considerable testing of recycled products for roadbase and has used road profilings, crushed concrete and crushed commingled demolition material successfully on many heavy duty roads.

This testing has shown that recycled commingled and recycled concrete roadbase is at least equivalent to virgin quarried roadbase. The commingled recycled roadbase withstands turning traffic movements exceedingly well, and this makes it a very suitable material for road rehabilitation (Leek 2008).

A number of tests, including repeat load triaxial testing, shear box testing and falling weight deflectometer testing have been undertaken on recycled crushed concrete and commingled recycled crushed roadbase which demonstrate roadbase manufactured from recycled demolition materials will perform equally, if not better than, newly quarried roadbase (Leek 2008).

Repeated load triaxial testing (Austroads test procedure)was undertaken on new and recycled materials by ARRB at the request of the City of Canning. These results are shown in Table 3.12. The quarried roadbase used in this test had previously been tested using the same test method as part of the City's ongoing investigations and had been shown to be the best quality roadbase produced in the Perth region (Leek 2008).

Table 3.12: Repeat load triaxial test results on new and recycled materials used in Welshpool Road trial

Material	Dry density (%MDD)	Moisture content (%OMC)	Resilient modulus (MPa)		
			Stage 1	Stage 2	Stage 3
Quarried roadbase	98.2	76	210	Failed	Failed
	98.3	66	250	260	Failed
	99.4	47	380	440	460
Recycled commingled base	97.5	77	250	270	220
	97.9	65	330	350	350
	98.0	60	400	430	440
Recycled concrete base	98.6	74	320	340	330
	98.3	66	500	530	490
	98.1	59	630	690	670

The testing indicated that:

- Recycled concrete roadbase has the highest strength and least moisture sensitivity of the three materials
- Recycled commingled roadbase has the next highest strength across a range of moisture contents, and
- Quarried roadbase had the lowest strength and was unstable at higher moisture contents.

This is a new test method, and results depend on the individual operator and sample preparation. Previous tests have been undertaken by ARRB and Main Roads WA using this method, and the Main Roads WA results and previous ARRB results are shown in Table.3.13:

Table.3.13: Historical repeat load triaxial tests results at 98% MDD and 80% OMC (Stage 3 Modulus)

Material	Modulus (MPa)
Commingled 25 mm C & D recycled base	500
Pure crushed concrete 25 mm C & D recycled base	430
Conventional 20 mm non-plastic roadbase company A	410
Conventional 20 mm low plasticity roadbase company A	370
Cement modified 20 mm roadbase company A	470
Conventional 20 mm low plasticity roadbase company B	650

Company B in Table.3.13 is the same supplier as that for Welshpool Road and this table shows that the roadbase with which the comparisons are made in Welshpool Road is a high quality product.

Falling Weight Deflectometer testing was undertaken on the completed pavement layers and results are shown in Table 3.14. The lower curvature values indicate that the recycled materials provide a stronger pavement than the quarried roadbase.

The modulus of the pavement layers can be calculated from the deflectometer results. The modulus is effectively a measure of material strength. The calculated modulus values of the different materials used are shown in Table 3.15. These again show that the recycled materials are stiffer, and hence likely to give a longer asphalt fatigue life than quarried roadbase.

It is noted that there is variability in the tests undertaken. A large number of tests need to be undertaken on both recycled and virgin material to give statistically reliable results. Overall the results indicated that recycled materials are equally as strong as new quarried roadbase.

Visual observations made during construction also showed some significant differences in material characteristics. Of particular note was the ability of the commingled recycled roadbase to withstand the effects of turning traffic. Welshpool Road carries a significant number of heavy vehicles including road trains. In one intersection in particular where road train turning movements were very high, the commingled material withstood turning traffic for 10 days prior to surfacing and showed only minor ravelling (loose stones) over this period. Quarried roadbase would not have withstood this type of road use.

It is concluded that recycled pavement materials are very suitable for road construction, and may outperform quarried roadbase. They are suitable for heavy used roads carrying heavy vehicles (up to 10,000,000 standard axles over the pavement life).

Table 3.14: Deflection and curvature values on completed layers of Welshpool Road

Pavement construction	Test level	Deflection			Curvature		
		Mean (mm)	Std dev (mm)	95th %ile (mm)	Mean (mm)	Std dev (mm)	95th %ile (mm)
150 mm roadbase/250 mm commingled recycled	Top base	0.59	0.06	0.65	0.21	0.03	0.25
400 mm commingled recycled	Top base	0.46	0.05	0.53	0.15	0.02	0.17
250 mm 50 mm commingled recycled	Top subbase	0.79	0.08	0.89	0.21	0.04	0.25
250 mm recycled concrete	Top subbase	0.81	0.22	1.09	0.23	0.07	0.31
150 mm recycled concrete/ 250 mm 50 mm commingled recycled	Top base	0.46	0.05	0.51	0.13	0.02	0.16
400 mm recycled concrete	Top base	0.49	0.05	0.57	0.15	0.03	0.20

Table 3.15: Back-calculated modulus of pavement layers in Welshpool Road

Pavement construction	EfromD3 Layer Modulus (MPa)			
	Test at base level		Test at subbase level	
	Base layer	Subbase layer	Top subbase	Bottom subbase
150 mm roadbase/ 250mm commingled recycled	641	722		
400 mm commingled recycled	1024	678		
250 mm 50 mm commingled recycled			1366	357
250 mm recycled concrete			940	484
150 mm recycled concrete/250 mm 50 mm commingled recycled	1275	505		
400 mm recycled concrete	1042	527		

3.6.3 Product quality and acceptance

The C&D Division of the Waste Management Association of Australia (WMAA) has produced a guideline to good practice as well as a document on asbestos management, which when coupled to accredited quality systems, ensure product quality (Noel Arnold & Associates 2005).

The City of Canning has engaged ASLABS Pty Ltd to undertake concrete mix designs for the manufacture of concrete using recycled concrete and commingled materials. As Canning is fortunate to have a concrete batching plant and agitator trucks, it has been able to use these designs to produce concrete for footpaths.

The concrete produced from sand and recycled commingled roadbase has been shown to be indistinguishable from that made of new materials. It is workable, gives a high standard of finish, and is cheaper to manufacture.

The variety of factors that should be considered in purchasing decisions these include:

- Cost of raw materials
- Long-term performance of raw materials
- Water use and energy used to work raw materials
- Energy used to produce the raw material
- Loss of habitat in producing the raw material
- Transport cost
- Energy used in transport of materials
- Disposal of demolition/box out materials
- Transport cost for demolition/box out materials, and
- Options for backloading road-making materials.

The ultimate decision on whether to use recycled materials will be based on material costs, transport costs and the ability to backload, but should also consider indirect costs such as fuel use, greenhouse gas emissions and conservation of resources.

In a 2009 Strategic Waste Initiative Scheme funded report into the quality of crushed roadbase, Bowman and Associates (2009) identify that:

> None of the four facilities can currently make RCRB (Recycled Crushed Road Base) products that meet all of the acceptance criteria in the Main Roads WA 501 Specification for basecourse. It is probable that all four facilities will be able to consistently produce RCRB material that meets the PSD (Particle Size Distribution) grading and liquid limit specification in the future. This can only be achieved through diligent work, careful raw feed selection, plant operation, production procedures, maintaining equipment in good working order and the use of “foreign materials” such as clay, crushed brick and sand to correct liquid limits. All facilities have shown that they can consistently produce RCRB material that meets the Specification for subbase.

This document should be read with the understanding that the test results showing variations in PSD were minor and that the liquid limit value is not a relevant stand-alone result for this material.

Recycled crushed demolition materials are also highly suited to pipe bedding in wet soils, and construction of filter beds for stormwater. They have been used for this purpose in high impact stormwater quality improvement projects such as the Wharf Street Wetlands in the City of Canning where subsurface flow wetlands using recycled crushed concrete have been constructed.

There are a number of Local Governments in and around the Perth metropolitan area using recycled materials including recycled roadbase, recycled aggregates and crushed concrete (used in new concrete manufacture by Canning, Gosnells, Rockingham, Belmont, Victoria Park, Cottesloe, Swan and Northam.

Recently the City of Canning used recycled concrete in subsurface flow wetlands for a stormwater nutrient intervention project. It was discovered that when water is in full contact with recycled concrete, very high alkalinity (pH12) can be induced in the water. As a result, it is recommended that recycled concrete not be used when it will be in an environment saturated with water.

There are no technical reasons preventing the use of recycled crushed demolition materials for road construction, drainage works and non-structural concrete applications in Local Government works, but not in situations where it will be exposed to standing water.

3.7 Container and plate glass

The use of container and plate glass in typical Local Government road building applications needs careful consideration. As discussed in Section 2.1, the waste hierarchy provides a guide for the use of recycled products. For glass, use as an aggregate in road or pavement is least preferred . It is, however, a higher end use than landfill.

WA currently has no ability to recycle glass into a glass product, which is the highest end use. Container glass from WA that is recycled is processed in Adelaide; the glass travels a distance of 2,685 km from Perth to Adelaide. Road transport over these distances is likely to be in a double bottom road train, which carries more weight but at higher fuel consumption, or a road-rail combination which is preferable. In estimating the environmental cost of glass recycling, refer to Table 3.3, which is based on UK conditions. This must be amended to account for the longer distances involved and consideration must also be given to the return journey. If the truck returns empty, the entire round trip needs to be factored in. This will give some indication of the energy use to recycle glass back into glass, compared to other uses.

The only viable option, for Local Governments to utilise, what would otherwise be waste glass, is as an aggregate replacement in concrete, drainage, asphalt and roadbase. In each of these applications, except drainage bedding, glass is replacing only the small aggregate sizes including the sand fraction.

As mentioned previously, the Shire of Augusta-Margaret River has invested in a glass crushing plant, and will divert glass currently trucked to Perth and railed to Adelaide. Whilst this may appear a lower order use, analysing the transport implications shows that it is an approximately energy neutral option, and will save extraction of some 800 tonnes per year of sand. Thus overall, it would appear to be an environmentally sound decision.

It is considered that for glass to be used as a replacement aggregate, it would be necessary to crush to less than 5 mm for safety and material performance reasons. The addition of glass in roadbase and/or road subbase at only 5% would consume 240 tonnes per km of 8 metre wide road.

There is no accurate information available on the quantity of plate glass and automotive glass currently being sent to landfill Australia-wide, however, an estimated 91,000 tonnes per annum are disposed to landfill (Davey 2008). Based purely on population, the WA portion is likely to be around 9,000 tonnes. Laminated glass is more difficult to process, and whilst the plastic laminate can be separated and used for shoe sole manufacture, this is unlikely to be viable in Western Australia. The City of Canning has expressed an intention to work with Pioneer Road Services and trial crush some of these waste glass streams in order to assess the possibilities for recycling this product.

Crushed glass can also be used for pipe bedding, and has been successfully demonstrated in a trial conducted in NSW (Department of Environment and Climate Change 2007). The Department of Environment and Climate Change agreed to facilitate the assessment of four samples of crushed glass prepared by Sydney recycler Benedict, on behalf of Sydney Water.

The material tested and trialled was produced from glass fines which are the residual glass left after the main recycling process occurs. The kerbside recycling is collected, sorted and all of the glass material above 30 mm in size is recycled; the residual from this process is delivered to Benedict Sand and Gravel for further processing (Department of Environment and Climate Change 2007).

The construction workers using the material commented that it handled as easily as natural sand and that they experienced no greater problems with odour, skin contact or dust (Department of Environment and Climate Change 2007).

4 Preliminary workshop and survey

The following is a brief summary of the outcomes of a workshop held at the City of Canning on December 3, 2008. A detailed description of the workshop is provided in Appendix A.

4.1 Preliminary workshop

In excess of 90 people attended, indicating the interest in recycling in Local Government. The workshop commenced with a series of short presentations:

- Construction waste and recycling – A national perspective: Bob Andrews, ARRB Group
- Recycled aggregates – environmental considerations: Jencie McRobert, RMCG Consultants
- Glass recycling and Midland magpies: Emma Shepherd, Midland Brick
- A convenient truth – Asphalt sensitive to nature: Meda Sicoe, Pioneer Road Services
- Introduction to the Construction & Demolition Working Group: Adrian Lester, C&D Recycling, and
- Welshpool Rd. – A demonstration project: Colin Leek, ARRB Group.

The presentations were followed by a question and answer session. The questions posed indicated a willingness to accept recycled products.

4.2 Workshop survey

Following the workshop, a survey was undertaken to determine the factors that either work towards or against the use of recycled products. Surveys were sent to 96 persons who had RSVP to the workshop. A response was received from 29 people (30%).

The survey sought to determine the acceptance or otherwise of recycled products and the reasons for acceptance or otherwise of recycled products.

Questions were asked in relation to each of the Section headings presented below. The responses to the questions are shown as a percentage of responses received and where applicable ratings are also expressed as a percentage.

Survey results for use of recycled material in road construction are shown Appendix A.

4.2.1 Workshop objectives

Did you find the workshop gave information that was useful to you or your organisation?

Yes-93%, No-0%, No comment-7%.

Rating- 66%

How would you rate the workshop in general?

Rating- 80%

Prior to attending the workshop, would you have considered using recycled products if they were offered to you for a road project?

Yes-76%, No-14%, No comment-10%

Following the workshop, have you now changed your view on recycled products in roadworks?

Yes-34%, No-55%, No comment-10%

4.2.2 Environmental considerations

Considering the following criteria, please rate the importance of various benefits of using recycled products:

Saving on landfill space? Rating- 90%

Saving on energy use?
Rating- 81%

Reduction of greenhouse gas emissions? Rating- 85%

Conservation of resources? Rating- 89%

Reduced habitat loss? Rating- 80%

Reuse of materials because it makes sense? Rating- 91%

4.2.3 Cost considerations

Considering the following cost implications, please answer the following:

I would use recycled materials only if they were cost neutral?

Yes-48%, No-34%, No comment-17%.

I would use recycled materials only if they were cheaper than new materials?

Yes-34%, No-45%, No comment-21%.

I would use recycled materials even if they cost more than new materials?

Yes-62%, No-21%, No comment-17%.

Of those prepared to pay additional, the amount extra they would pay ranged from 2% to 30% with the average being 14%.

4.2.4 Technical considerations

Considering the following performance criteria, please indicate your level of confidence:

How confident are you in the performance of recycled products?
Rating- 79%

How confident are you in the quality control of recycled products?
Rating- 75%

At the present time would you reject using recycled products due to performance or quality concerns?

Yes-21%, No-59%, No comment-34%.

Are you confident that recycled materials can be supplied in sufficient quantities?

Yes-59%, No-34%, No comment-7%.

4.2.5 Balanced cost considerations

Questions were asked to ascertain how organisations currently assess tenders and quotations for services and products, and whether subsequently to the workshop, they would consider other costs related to environmental and social aspects of producing that product.

Do you currently consider supply tenders or quotes on cost only?

Yes-21%, No-62%, No comment-17%.

If you answered No above, which of the following factors do you currently consider?

Energy use?	Yes-14%, No-24%, No comment-62%.
Greenhouse gas emissions?	Yes-17%, No-24%, No comment-59%.
Conservation of resources?	Yes-24%, No-17%, No comment-59%.

Of those that do have assessment criteria, only a very small number consider greenhouse gas emissions and conservation of resources in their assessment process.

4.2.6 Use of recycled products in construction

Considering the case studies presented, would you consider using the following products in road construction? If yes, please rate how confident you are for each use.

Recycled pure crushed concrete:

Subbase in light traffic roads?	Yes-79%, No-0%,	No comment-21%.	Rating- 79%
Subbase in heavy traffic roads?	Yes-72%, No-7%,	No comment-21%.	Rating- 77%
Base in light traffic roads?	Yes-72%, No-7%,	No comment-21%.	Rating- 63%
Base in heavy traffic roads?	Yes-59%, No-17%,	No comment-24%.	Rating- 54%

Recycled commingled demolition materials (concrete with brick, asphalt, tiles):

Subbase in light traffic roads?	Yes-79%, No-3%,	No comment-17%.	Rating- 72%
Subbase in heavy traffic roads?	Yes-62%, No-14%,	No comment-24%.	Rating- 69%
Base in light traffic roads?	Yes-66%, No-10%,	No comment-24%.	Rating- 59%
Base in heavy traffic roads?	Yes-52%, No-28%,	No comment-21%.	Rating- 53%

Recycled crushed glass:

As part aggregate replacement in asphalt?
Yes-76%, No-7%, No comment-17%. Rating- 84%

As part aggregate in subbase? Yes-62%, No-21%, No comment-17%. Rating- 69%

As part aggregate in base? Yes-52%, No-28%, No comment-17%. Rating- 63%

Recycled crumbed rubber:

As binder supplement in hot bitumen? Yes-72%, No-10%, No comment-17%. Rating- 73%

Added to aggregate in asphalt plant? Yes-72%, No-10%, No comment-17%. Rating- 73%

Considering the case studies presented, would you consider using the following products in concrete for footpaths?

Recycled crushed demolition materials? Yes-90%, No-0%, No comment-10%. Rating- 81%

Recycled crushed glass? Yes-86%, No-3%, No comment-10%. Rating- 84%

4.2.7 Landfill levy

Considering landfill operations, please answer the following:

Do you consider a landfill levy as being a good way of diverting products from landfill?

Yes-69%, No-21%, No comment-10%.

Do you think a levy should be a flat rate for all materials?

Yes-3%, No-83%, No comment-10%.

Do you think a levy should be higher for products that can be easily recycled?

Yes-69%, No-17%, No comment-14%.

Do you think a levy should be lower for products that are difficult or cannot be recycled?

Yes-55%, No-28%, No comment-17%.

Have you noticed a relationship between landfill costs and illegal dumping?

Yes-45%, No-28%, No comment-28%.

Do you think that regulation to prevent recyclables being landfilled is desirable?

Yes-79%, No-14%, No comment-7%.

5 Increasing the use of recycled products

There are many products in the waste stream that can be utilised in Local Government applications. Table 5.1 lists materials already discussed and others with potential to be recycled in Local Government applications.

Table 5.1: Recyclable materials and potential uses

Material	Product	Potential uses
Construction and demolition materials	Continuously graded aggregates	Road base
		Subbase
		Select fill
		Non structural concrete
	Select graded aggregate	Structural concrete
		Filter medium
		Pipe bedding
Glass – container and plate	Fine aggregate	Asphalt manufacture
		Pipe bedding
		Filter material
		Fine aggregate in roadbase
		Concrete manufacture
Tyres	Whole tyres	Civil construction
		Erosion mats
		Bank stabilisation
		Retaining structures
	Baled tyres	Retaining structures
		Lightweight 'floating' crossings of low strength soils
	Crumbed rubber	Asphalt manufacture – improved fatigue and rut resistance
		Manufacture of soft matting
		Manufacture of speed humps, kerbs, roundabouts etc.
	Tyre derived fuel (TDF)	Firing kilns for cement and brick manufacture
Used oil	Oil derived fuel	Asphalt manufacture
	Refined oil products	Lubricating oils in vehicle fleets
		Diesel fuel
	Oil bottoms	Bitumen supplement for stabilisation and asphalt
Plastics	Various manufactured products	Drainage pipes
		Playground equipment
		Traffic control devices
Reclaimed asphalt pavement (RAP)	Aggregate	Hard stands
		Asphalt manufacture
		Road base
		Subbase
Excavated materials	Screened sand	Select fill
		Landscaping
	Clay	Brick and tile manufacture
		Lining of dams and constructed wetlands

5.1 General considerations

In the recycling of any product, the waste hierarchy of reduce, reuse, recycle, dispose should be followed. Care should be taken to ensure that the optimum outcome for that material is achieved. In order to ensure that this is the case, the total life cycle of products needs to be considered and compared.

Considering a hierarchy for use of materials, the following hierarchy is presented which minimises total environmental impacts and makes best use of the stored energy within the material:

- Reduce – saves resources, energy and is the highest option
- Reuse again for same purpose – this is the next best option, as a product needs to be made only once
- Reuse again for another purpose – this is the third order option, but requires more consideration in terms of energy savings
- Recycle to remanufacture same product
- Recycle to a different product – this is the fifth option, but depending on a total analysis could become the third or fourth level option. Note also that this may be recycling to energy in the case of incineration
- Dispose to alternative site – this is the sixth level option, where a product with no other use may be disposed in a planned manner. An example would be filling an infiltration/retention basin with used tyres and filling with aggregate. The tyres may serve no useful function, but they have been safely disposed, and
- Dispose to landfill – this is the least desirable option and should be a last resort. Despite the issues with landfill, however, putrescible wastes discharged to landfill can be used to generate energy, thus complicating the analysis.

5.2 Recycling potential in Local Government

The response to the Workshop held, indicates a growing interest and awareness in the use of recycled products in road application. Also Local Government and industry investment in infrastructure, for example the Shire of Augusta-Margaret River and Pioneer Road Services, indicates a willingness and interest in using recycled products in road application.

This Report concentrates on the three major products that are most applicable to Local Government. These are:

- Materials sourced from commercial and demolition materials
- Container glass other than that recovered for reprocessing, and
- Used vehicle tyres.

The products which are easiest to address are the use of recycled demolition materials in road and drainage construction and the use of crumb rubber in asphalt. Both of these processes are well understood and studied, and there are current specifications both within Main Roads WA and interstate that can be used as models for an Institute of Public Works Engineering Australia specification for distribution to Local Governments.

Recycling of glass into asphalt has been undertaken, and once Pioneer Road Services has commenced production of glass asphalt for the City of Canning, test data will follow to increase awareness and confidence in the use of glass.

Similarly, glass will be added to recycled commingled roadbase in an upcoming project at the City of Canning to give data and evidence of the practicalities of incorporating glass in roadbase.

Whilst glass and recycled demolition materials can be used to manufacture concrete this would need to be taken up by the concrete industry to allow use by other Local Governments. Most concrete companies in WA are vertically integrated and have their own quarries which supply their batch plants. There may be considerable resistance by these companies to supply concrete using recycled materials, both from the diversion of markets for their quarries, and from the logistical point of having to have more material bins and mix designs.

Recycling of tyres in Local Government road applications may be achieved either as crumb rubber in asphalt, but at a significant cost increase, or by purchasing policies for playground equipment that favour products made from recycled rubber. Whole tyres may be used for specific civil engineering applications such as retaining and erosion control structures, but tyres may not always be suitable for these applications, and the numbers used will be small.

5.3 Inhibitors and actions to increase use of recycled products

It would appear from the workshop and the survey response that many people in Local Government are aware of the need to recycle and would like to do so. The inhibitors to recycling and possible solution are shown in Table 5.2.

Table 5.2: Inhibitors to use of and actions required to overcome inhibitors to use of recycled products

Inhibitors	Actions
It is easier to continue doing the same thing over and over again than to adapt to change and introduce new methods.	Identify champions to undertake more demonstration projects in receptive Local Governments.
A lack of confidence in the performance of recycled products as recycled is often viewed as second hand and second class.	Undertaking detailed testing and dissemination of test results.
A perception that by using a non-standard product, there is a higher level of risk in pavement performance.	Disseminate consistency reports by independent laboratories undertaken as a SWIS grant project.
A lack of hard data and prior examples of local use of recycled products.	Run workshops to disseminate examples of successful use of recycled products.
A lack of availability of recycled products.	Increase landfill levy to encourage greater diversion of recycled products.
An historical carryover of the poor quality control of early recycled products.	Develop and disseminate specifications for use of recycled products including: • crushed glass in roadbase and asphalt; • recycled roadbase made from demolition materials; • crumb rubber asphalt; • non-structural concrete. Ensure that quality control methods used by recyclers is well known, documented and disseminated. Note: Waste Management Association of Australia Construction and Demolition Division is working this.

Inhibitors	Actions
Concern about contaminants including heavy metals, poisons and asbestos.	Develop appropriate quality management systems and source separation.
Little understanding of the total environmental footprint of products.	Undertake further studies to quantify environmental footprint of various products and disseminate at workshops.
Lack of appreciation of value of demolition and waste materials, widespread community view that waste = worthless.	Ensure comprehensive public and industry education on the value of recycled products.
Cheap supply of raw materials makes recycling unprofitable.	Introduction of a resource tax to reflect true costs of producing new materials. Introduce true triple bottom line accounting to cost environmental and social costs including greenhouse gas emissions.
Rejection of mixed loads by recycling plant as material too difficult to handle.	Educate workforce to benefits of separation at source.
Vertical integration of concrete plants and aggregate quarries.	Insert 'preference to recycled product' clauses into specifications. Analyse tenders on total environmental cost basis.
Expense of converting systems to utilise recycled components.	Subsidise from landfill levy. Introduce mandatory requirements for recycled content into supply contracts.
Lack of incentives to use recycled materials.	Education campaign to explain other less tangible benefits of using recycled materials. Subsidise recycled materials from landfill levy.
Recycled materials require different approach to usual methods.	Undertake trials and educate crews about environmental and structural benefits.
No requirement for developers to submit waste management plans.	Include regulations in the Waste Avoidance and Resource Recovery Act for waste management plans with priority to reuse existing materials within development.

5.4 Process framework for introduction of recycled materials into roadworks

5.4.1 General

A framework for facilitating the increased use of recycled content by WALGA in construction and maintenance of footpaths, cycle paths, local roads and other appropriate infrastructure is illustrated in Figure 5.1 (McRobert et al 2000).

It is based on the Australian Standard for Risk Management (AS4360:1999). The framework provides an overall approach in which decisions concerning material needs, material sources, material characterisation, risk assessment and treatment, project use and operational phase issues can be considered.

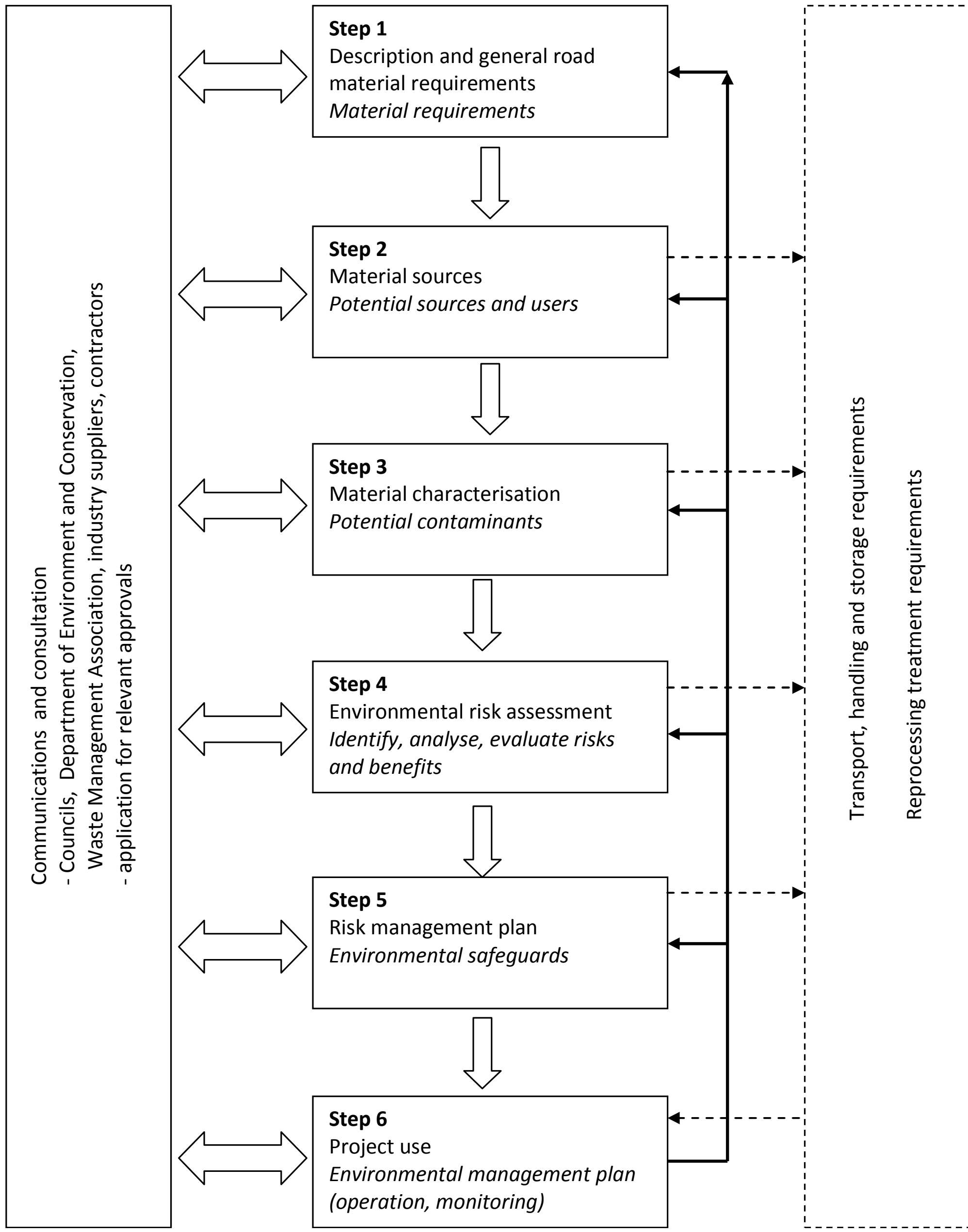


Figure 5.1: Suggested framework for guidelines on materials use in roadworks

5.4.2 Details of the framework

Step 1: Description and general road material requirements

Discuss all the relevant factors, including technical and environmental characteristics. These can include, but not be limited to:

- Wider project context, including the strategic importance of the project, infrastructure capacity requirements and uses
- Environmental impact assessments and development approvals, permits, relevant catchment or regional management plans, etc.
- Location and environmental values description (proximity, sensitivity) and the potential risks associated with the use of recycled materials in relation to contaminant leaching
- Project specific baseline site, soil and water characteristics, including desktop studies of available information relating to underlying geochemical profile
- Project specific existing/prior land uses
- Project specific factors such as hydrology (groundwater, surface drainage), topography, climate and geology (soils), and
- Project specific location and design issues including materials quantities, quality and performance requirements.

Step 2: Identify materials sources

A literature search and desktop study can identify the potential material sources available. Key engineering considerations, economic feasibility and environmental factors to be identified include:

- Identification of the types of products required for the project and where incorporation of recycling materials can be incorporated e.g., roadbase layers, concrete structures, plastic and rubber products etc.
- Potential project uses including structural fill, subbase and base material, drainage layers, embankment fills, substitute for asphalt, aggregate and granular base, fence posts, road safety bars, roadside furniture, etc.
- Potential sources of recycled materials from existing industries
- Availability of commercial materials e.g. to meet project delivery quantities, and
- Logistics of location and transport impacts involved e.g. transport on-costs, heavy vehicle network impacts.

The following recycled materials may generally be available for use on road construction:

- Low level contaminated soils
- Recycled concrete/brick
- Reclaimed asphalt blends
- Glass
- Waste water
- Tyre/rubber materials

- Bio solids
- Used oil, and
- Fly ash, bottom ash and industrial slag.

Step 3. Material characterisation

Describe materials characteristics, including:

- Structural/mechanical properties
- Chemical composition (physical characteristics are covered in other guidelines/specifications)
- pH, conductivity, concentration of trace metals, sulphates, total carbon, total dissolved solids, total suspended solids, etc.
- Sampling guidelines, e.g. National Environment Protection Council Schedule B(2) Guidelines on Data Collection, Sample Design and Reporting, National Environment Protection Measure, Assessment of Contaminated Sites 1999
- Testing guidelines, e.g. National Environment Protection Council, Standards Australia, Australian and New Zealand Environment Conservation Council, Department of Environment and Conservation , etc.
- Potential contaminants, and
- Assess likely treatments required.

Material classification could be based on:

- Environmental classifications such as those for ‘clean fill’, ‘intermediate landfill cover’ or ‘low level contaminated’, or
- If classified as ‘clean fill’ then proceed to Step 6; otherwise proceed to Step 4 which may require the appointment of an environmental specialist.

Step 4: Environmental risk assessment

(a) Identify potential hazards based on the materials classification in Step 3 and identify project activities and phases that may create environmental hazards (e.g. construction phase, operation phase).

(b) Identify exposure mechanisms and environmental exposure mechanisms, including:

- Water quality impacts via leachate
- Air quality impacts, e.g. dust
- Land contamination resulting from construction activities, e.g. exposure of acid sulphate soils
- Vegetation impacts associated with clearance, and
- Fauna impact (i.e. habitat disturbance) – identify interactions and secondary stressors.

(c) Identify environmental receptors:

- Describe environmental sensitivities associated with the receiving environment, including water, land, soil, air quality, vegetation, fauna values and human amenity (e.g. noise). For example, does the site contain any of the following site conditions shown in Table 5.3.

Table 5.3: Environmental sensitivities associated with the receiving environment

Groundwater factors	Surface drainage factors	Soil factors	Proximity to high value or sensitive areas
High watertable	Susceptibility to flooding	Presence of acid sulphate soils	Within 50 m of a watercourse or wetland
Background pollutant levels	Tidal influence	Soils prone to subsidence	Nearby remnant vegetation
Acid or saline groundwater	Drainage paths	High permeability soils	Nearby habitat for native species

(McRobert et al 2000)

(d) Evaluate environmental risk:

- Estimate likelihood and consequences/severity of environmental exposures associated with identified mechanisms.
- Is the risk exposure acceptable?
- Are the acceptability criteria OK? If so, proceed to Step 6.
- Is a risk management plan required to reduce likelihood, control consequences or avoid risks? If so, proceed to Step 5.

Step 5: Risk management plan

Identify appropriate environmental safeguards and the range of risk treatment options to be considered, including:

- Materials pre-processing
- Encapsulation
- Leachate barriers, collection and containment system, and
- Neutralisation.

Step 6: Project use

Describe implementation requirements included in the Environmental Management Plan (operations), including:

- Post-construction monitoring requirements (e.g. ground water, frequency of testing)
- Sampling, and
- Auditing.

5.4.3 Example adaption of the framework to Western Australian Local Government requirements

The framework can be used to determine the suitability of any waste that can be recycled into a useable resource.

Within the context of this report, the framework can be demonstrated as follows:

Step 1: Description and general road material requirements

The incorporation of recycled materials and products into Local Government construction and maintenance of footpaths, cycle paths, local roads and other appropriate infrastructure is based upon minimising waste to landfill.

There are many materials in the waste stream that are suitable for reuse or recycling and this framework is limited to:

- Construction and demolition wastes
- Container glass
- Tyres, and
- Used oil.

Step 2: Identify materials/products and potential sources

Construction and demolition waste recycling is common throughout Australasia as a successful commercial industry. The products produced clearly show a proven ability to be considered as

- Granular, modified and stabilised (bound) pavement material
- Concrete aggregates
- Backfill and bedding sand
- Drainage mediums, and
- Fill materials.

In WA there are three commercial operations processing C&D waste into granular pavement materials which whilst not strictly in accordance with Main Roads specifications, are highly suitable for road construction.

Glass recycling into other uses than container reuse is an emerging technology in Australasia with application for:

- Replacement aggregate in concrete
- Drainage mediums
- Inclusion into granular pavement material, and
- Introduction into hot mix asphalt.

Currently glass recycling facilities are being established in WA and are in their early stages of commercial operation.

There are many products that can be manufactured from processed tyre products that have applications in Local Government. These include:

- Rubber roundabouts
- Rubber speed humps and speed cushions
- Rubber crash cushions
- Rubber kerbs
- Bases for cones and bollards
- Soft paving for playgrounds, and
- Rubber slabs for temporary paths, stages and crossovers.

All of these products are available off-the-shelf and have been used in Local Government applications and should be encouraged.

In addition, granulated rubber can be incorporated into the bitumen used in spray seals and asphalt. The use of tyres for civil engineering applications including retaining walls, erosion control structures, covered infiltration basins and pavements in soft ground have been adopted throughout Australasia.

Used oil is collected in WA, and reprocessed to a burner fuel. The market for such fuel in WA is limited, and most is exported to Singapore. Reprocessing facilities for re-refining used oil for lubricants and bitumen is currently in the development phase.

Step 3: Materials characterisation

The structural characterisation of pavement material products sourced from C&D waste is well documented throughout Australasia. In WA, the Welshpool road trial undertaken by the City of Canning provides local information on the integrity of the product. In addition MRDWA has introduced a revised specification 501 (April 2009) that suggests the material is suitable for traffic loadings up to 5 x 106 ESA.

In the manufacture of a recycled (any) product, it must be ensured that it is manufactured under a quality assured environment, and term supply to WALGA members should require accreditation to ISO 9000 standards'.

Control of asbestos and other contaminants (heavy metals, poisons and hydrocarbons) is governed by State legislation and National Environment Protection Council Guidelines.

The use of products sourced from crushed glass are not currently available in WA however if used in concrete manufacture, hot washing prior to crushing to remove sugars is essential.

The use of tyres is restricted in WA when used as retaining structures for fear of contamination of the surrounding environment. Whilst there are many examples of usage throughout Australasia, further consideration of legislation is required.

Step 4: Environmental risk assessment

The assessment of risk must be based at the project level and cannot be considered here at the strategic level in any detail.

The use of products sourced from C&D waste must comply with legislation associated with asbestos management and a national industry guideline has been produced by the Waste

Management Association of Australia (WMAA) in order to negate these risks. In addition, compliance with legislation associated with leachate contaminants is required.

There are no appreciable risks associated with the use of crushed glass in infrastructure provided that it meets a consistent standard specification developed and tested for a particular application.

Step 5: Risk management plan

Risk treatments are project and site specific. It will be necessary for a risk assessment to be undertaken prior to the application of recycled materials in a project. This is not specific to recycled products, and should be applied to the use of new products as well, such as assessment for the spread of dieback or other plant diseases by road-making materials.

Step 6: Project use

Having used recycled materials, their performance requires monitoring for such considerations as:

- Structural integrity
- Constructability
- Economics
- Product quality and uniformity
- Environmental contamination
- Net energy usage
- Greenhouse gas emissions, and
- Fit for purpose evaluation.

6 Western Australian Local Government Association policy development

6.1 Western Australian Local Government Association background

The West Australian Local Government Association (WALGA) is the voice of Local Government in Western Australia. As the peak industry body WALGA is an independent, membership-based group representing and supporting the work and the interests of 139 Local Governments.

The Association provides an essential voice for almost 1,300 elected members and over 11,000 employees of Western Australia and Christmas Island and Cocos (Keeling) Island Councils. WALGA also provides professional advice and offers services that provide financial benefits to the Local Governments and the communities they serve.

The Western Australian Local Government Association is divided into Policy Teams, each of which has a number of priority issues and the Association focuses mainly on policies that relate to these particular issues. These areas are:

- Community and Development;

- Environment and Waste
- Governance and Strategy, and
- Infrastructure.

The strategic objectives of the Western Australian Local Government Association are:

- Representation of Local Government interests
- Effective leadership of the Local Government sector
- Promotion of a positive profile for Local Government, and
- Enhancement of the capacity of Local Government.

This report falls under the Infrastructure portfolio, but is of interest to the Environment and Waste area.

6.2 Current Western Australian Local Government Association position on waste management

WALGA has already developed a policy position in relation to State and Federal Governments regulatory framework to promote waste minimisation, recycling and efficient waste disposal. This includes policy statements on Extended Producer Responsibility, Waste Legislation, Landfill Levies and Strategic Waste Funding. These existing policy positions need to be considered in the development of policy positions related to the use of waste material, to ensure policy documents are consistent.

WALGA is currently drafting a Sustainable Procurement Guide, which will overlap to some extent further policy development on the use of recycled materials in Local Government works.

6.3 Current Western Australian Local Government Association position on reuse of recycled materials

WALGA currently has no formal position on the reuse of recycled materials in any of the many activities in which Local Government is involved. This report was commissioned by the Association to assist in the formulation of a policy position.

WALGA can encourage the use of recycled materials in road and other infrastructure by supporting the establishment of a centre for knowledge transfer in this field. This may be achieved by some or all of the following actions:

- Obtaining support from identified Local Governments already involved in reuse of materials to develop model specifications
- Developing a series of template policy positions that may be adopted by member Local Governments particularly in the reuse/recycling areas
- Working with identified Local Governments and actively seeking support from other Local Governments to continue research and development of recycling opportunities and establishment of trial and demonstration projects, and
- In conjunction with Local Governments already involved in reuse of materials, investigating practical uses for glass.

Whilst landfill may be an undesirable method of waste treatment, it is likely to be a significant method for the foreseeable future. Landfill sites are limited, and the conservation of landfill space is a high priority.

6.4 Western Australian Local Government Association policy position on use of recycled products in Local Government infrastructure

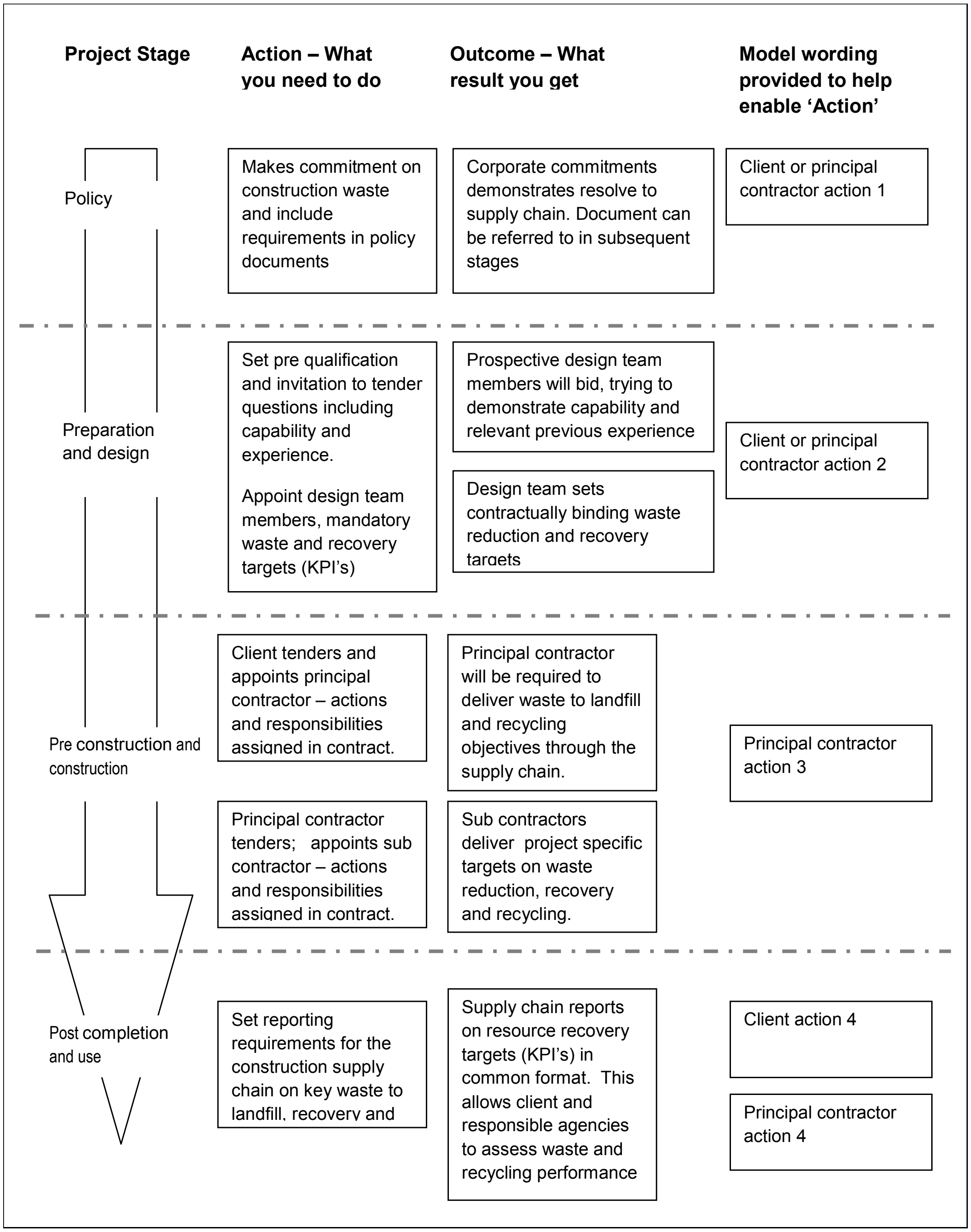
6.4.1 Objective

The objective of this report is to examine state policy and recommend strategies to encourage waste minimisation by obtaining maximum reuse of currently wasted resources and the preferential use of recycled materials in Local Government infrastructure development.

6.4.2 Policy development – UK

The UK Waste and Resources Program (WRAP) has produced a guide to assist construction clients and contractors in delivering corporate targets that support reduction of waste to landfill initiatives. The process is presented in Figure 6.1. (WRAP 2009 Model Procurement Requirements).

Figure 6.1: WRAP procurement process reducing waste to landfill



(Adapted from UK Waste and Resources Program (WRAP) Model Procurement Requirements)

6.5 Recommendations

The following suggestions are proposed as in-principle statements for further development by WALGA to form the basis of a policy document dealing with increasing the supply and preferential use of recycled materials for infrastructure.

The following actions are recommended to assist in promoting the most efficient use of resources:

1. That the Western Australian Local Government Association develop a policy on the use of recycled products in road construction and maintenance activities.
2. That the Western Australian Local Government Association develop an education and awareness package for distribution to all Local Governments in Western Australia. This will be in the form of:
   - workshops to disseminate examples of successful use of recycled products;
   - dissemination of the report: *Recycled concrete roadbase quality investigation: report for SWIS (Strategic waste initiative scheme)grant 4003* (Bowman & Associates, 2009), demonstrating the quality control mechanisms in place by the major C&D recyclers;
   - promotion of existing and future specifications for use of recycled products including
     - Crushed glass in roadbase and asphalt
     - Recycled roadbase made from demolition materials
     - Crumb rubber asphalt, and
     - Non-structural concrete.
3. That the Western Australian Local Government Association will establish a preferred supplier arrangement for the supply of recycled road building materials which would include C & D recyclers.
   - Consideration in the preferred supplier arrangement will be given to the inclusion of requirements for Quality Management Systems incorporating process control.
4. That the Western Australian Local Government Association instigate further studies to quantify the whole of life environmental footprint of roadbase and aggregates from both new and recycled products, including input energy consumption and greenhouse gas emissions at manufacture and processing, effects on habitat and sustainability of supplies. The findings will be disseminated at regional workshops.
5. That the Western Australian Local Government Association advocate to the State Government to have the landfill levy for inert materials raised to a value in line with other states, in order to allow the recycling industry to remain competitive and to generate more funds for research into diversion of waste from landfill.
6. That the Western Australian Local Government Association advocate that the State Government allows the subsidisation from the landfill levy to support future recycling initiatives for glass, tyres and oil as they arise.
7. That the Western Australian Local Government Association advocate to the State Government that requirements for waste management plans be mandatory for all large scale State and private projects involving major demolition works.
8. That the Western Australian Local Government Association include specifications for the supply of recycled materials in road construction and maintenance activities as and when appropriate specifications are developed and accepted by industry associations.

9. That the Western Australian Local Government Association promote to Industry Associations and Training Councils inclusion of specific issues relating to the use of recycled products in road construction and maintenance activities.

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8 Glossary of Terms

The following table provides an explanation of terms and their meanings as applicable to this report.

Term	Description
Aggregate	Term used to describe particles generated by the crushing of hard rock
alkali-silica reaction	A chemical reaction between alkali or cement based materials and materials composed of silica
Asphalt	A blend of graded aggregate, sand, filler and bitumen used for road surfacing
basecourse	The uppermost layer of granular material in a road pavement providing support for the pavement surface of a chip seal or asphalt
Binder	Any material which causes a binding action between aggregate particles
box out	To remove existing soil for the placement of roadbase or sub base
cementitious	A material with an alkaline cement based binder
ceramics	A glass like material with very high melting point used for making cookware
Carbon dioxide equivalent	A form used to describe the equivalent tonnes of all greenhouse gas emissions expressed as the equivalent amount of carbon dioxide
commingled	A recycled granular material composed of several types of demolition material, typically concrete, tiles, bricks and asphalt
commercial and industrial	Wastes collected in bulk from commercial premises (shopping centres) and industrial premises, usually very mixed and contains organics and packaging
construction and demolition	Wastes generated by demolition or during construction of engineered structures
container glass	Glass generated from bottles and jars
continuously graded aggregate	A material made up of various quantities of specific sized aggregates to create a continuous engineered grading for specific properties
Cullet	Processed recovered glass pieces used for feedstock in new glass manufacture
embodied energy	The energy used to manufacture an article taking into account all inputs from material extraction, processing, transport, recycling and disposal, but not including energy produced as a by-product of using that product, e.g. a motor vehicle has embodied energy by virtue of its manufacture, but uses energy in its operation
dispose	To discard either legally in landfill or illegally to the environment
equivalent passenger units (EPU)	A term used to allow convenient measurement of different sized tyres
greenhouse gas	Any gas that contributes to the greenhouse gas effect by creating an insulating layer that prevents or limits radiation of heat from the sun back into space
joules (J)	A unit of energy equivalent to lifting approximately a 0.1 kg weight 1 m

Term	Description
kerbside	The term used in waste collection where bins are emptied from the edge of the road
kWh	A unit of electrical energy equivalent to a 1 kW power source operating for 1 hour. A very fit cyclist can generate approximately 0.05 kWh. 1 kWh = 3.6 MJ
Landfill levy	A levy applied to materials taken to a landfill site and used to fund waste reuse initiatives
Oxides of nitrogen	Any gaseous compound of nitrogen and oxygen, usually NO or NO_2
oil bottoms	Heavy residue at bottom of tank from oil re-refining process containing the most contaminants
pipe bedding	A material used to lay pipes on in poor ground conditions to support pipes and allow greater control on levels
plate glass	Glass used for windows and windscreen manufacture
pozzolonic	A material that when mixed with calcium hydroxide develops cementitious properties
Product Stewardship for Oil (PSO)	A scheme by which a levy is applied to all oil and grease sales to fund a levy which is used to subsidise industries reclaiming used oil and producing value added products
putrescible	Solid waste that contains organic matter capable of being decomposed by microorganisms and of such a character and proportion as to cause oxides of nitrogenous odours and to be capable of attracting or providing food for birds or animals
RAP	Reclaimed asphalt pavement
ravelling	Loss of surface bonding leading to a loose surface with loose aggregate rather than a tightly bound surface
recycle	The act of converting a used product into another product for a different function
Reduce	The act of refraining to use an item
Reuse	The act of recovering a used product and reusing for the same purpose
roadbase	A high quality graded granular material made of crushed hard rock or recycled material
select fill	A high quality fill material of better quality than existing soil
subbase	The lower layer of granular material in a road pavement providing support for the pavement basecourse
Strategic Waste Initiative Scheme (SWIS)	A scheme by which funding from the landfill levy is directed towards waste reduction initiatives
Tyre Landfill Exclusion Zone (TLEZ)	Those zones of WA where tyres are prohibited from landfill unless baled and buried at a specific site
tyre derived fuel (TDF)	A fuel derived from the oil content of tyres

Appendix A Preliminary Workshop

A.1 Introduction

A workshop was held at the City of Canning on 3 December 2008. In excess of 90 people attended, which was in excess of registrations, indicating the interest in recycling in Local Government. The workshop commenced with a series of short presentations:

- Construction waste and recycling – A national perspective: Bob Andrews, ARRB Group
- Recycled aggregates – environmental considerations: Jencie McRobert, RMCG Consultants
- Glass recycling and Midland magpies: Emma Shepherd, Midland Brick
- A convenient truth – Asphalt sensitive to nature: Meda Sicoe, Pioneer Road Services
- Introduction to the Construction & Demolition Working Group: Adrian Lester, C&D Recycling
- Welshpool Rd. – A demonstration project: Colin Leek, ARRB Group.

Bob Andrews gave a background to the national situation regarding the recycling of demolition materials. Of particular note was the three goals set by the National Working Group.

- GOAL 1: Towards 'seamless acceptance' of fit for purpose engineering materials for use in road pavements and engineered fills by:
  - Improving market awareness of the technical capabilities of using recycled materials in road pavements
  - Providing guidance in the application of recycled materials to specific conditions
  - Detailing environmental benefits associated with their use including reductions in greenhouse emissions, and
  - Providing performance assurance in the use of recycled materials in road pavements.
- GOAL 2: To improve the operational performance of the industry through:
  - Development of a 'code of best practice for waste processing in the construction and demolition industries'
  - Developing a third party accreditation system for the operational performance of the industry
  - ISO quality accreditation of industry products, and
  - Providing guidelines for asbestos and contaminant control.
- GOAL 3: Provide an information reference and retrieval facility of national and international developments by:
  - Creating an adjunct C&D Division website to the WMAA website to include a library reference to national and international conference papers reports etc.
  - Developing technical notes on use of recycled materials
  - Providing access to product specifications and standards, and

  – Specific work practices associated with recycled pavement materials including OH&S issues.

Jencie McRobert provided detailed information on the comparative energy consumption of using recycled and new quarried products. Of particular note was:

- Total carbon dioxide equivalent per unit of production (preliminary):
  – SA Resourceco study – 3 kg carbon dioxide equivalent per tonne (21 MJ/t)
  – Victorian quarry study – 7.5 kg carbon dioxide equivalent per tonne (31 MJ/t), and
  – Embodied energy of recycled aggregates is approx. 30% less and emissions are approx. 60% less than quarried product.
- Relative carbon dioxide equivalent emissions:
  – Recycled roadbase (100%) = 24 t/km, and
  – Quarried roadbase (100%) = 72 t/km.

Emma Shepherd provided details of a Midland Brick initiative to recover used or left over bricks from demolition and construction sites and to recycle these into brick manufacture. She also outlined the new proposal to recycle ground glass into brick manufacture. Whilst not specific to Local Government, this presentation highlighted the opportunities available to those prepared to think laterally in ways to reduce our environmental footprint. Some of the major points were:

- Clay brick is 100% recyclable into new bricks
- The inclusion of pre-fired brick and ground glass reduces emissions and firing temperatures, with other benefits
- Trials of glass in brick manufacture in the UK and the USA have had promising results including:
  – Reduced firing temperature (energy and greenhouse savings)
  – Removal of vanadium staining issue
  – Reductions of emissions to air (cleaner air)
  – Removal of significant waste stream (less landfill), and
  – Reduced use of virgin materials.

Meda Sicoe presented details on the Pioneer Road Services trials on glass and rubber in asphalt. Based on previous trials, Pioneer Road Services has purchased a crushing plant from the United States, which is currently being assembled. Meda provided some very enlightening statistics about the waste generated per capita by several developed countries as shown in Table A. 1, which demonstrates that Australia does not have a good track record with regard to waste minimisation.

Table A. 1: Waste generated per person in selected countries

Country	Tonnes waste per annum per person
USA	0.88
Australia	0.74
Canada	0.50
Denmark	0.40
Japan	0.35
Germany	0.34
Switzerland	0.32
Sweden	0.28

Country	Tonnes waste per annum per person
France	0.26
U.K.	0.25

The waste generated in various Australian states is shown in Table A. 2.

Table A. 2: Waste and recycling quantities on a state basis

Waste stream	Municipal	Commercial & industrial	Construction & demolition	Total recycled	Diversion rate
State	x1,000 tonnes /annum				%
NSW	1156	1365	3309	5830	48
Vic	774	1740	1945	4429	51
Qld	445	212	488	1251	31
WA	92	344	410	826	23
SA	235	469	1452	2156	63
ACT	29	52	223	467	69
Australia	2701	4162	7827	14959	46

Note: Figures not available for Northern Territory or Tasmania

Some of the advantages of glass in asphalt are:

- Glass asphalt surfaces are more reflective than conventional asphalt – improves night-time road visibility
- The surface dries faster than traditional paving after rain because the glass particles do not absorb water
- Thousands of tonnes of waste glass now being sent to landfill sites can be used in asphalt production to improve the asphalt properties
- Due to the glass content the asphalt will hold heat longer than conventional asphalt so it is easier to work and compact, and
- Meets the asphalt volumetric properties required for 35, 50 or 75 Marshall Blows.

Limitations for glass in asphalt are:

- When more than 15% of glass is added it is necessary to add hydrated lime or other anti-stripping agents
- For asphalt wearing surfaces the ideal size of crushed glass is 3 mm, and
- Bigger sizes of crushed glass (5-20 mm) can be used in asphalt intermediate or basecourse.

Advantages of crumb rubber in asphalt listed were:

- Improves resistance to cracking
- Improves resistance to rutting
- Improves skid resistance
- Improves the fatigue resistance, and
- Reduces the tyre noise levels.

Adrian Lester outlined the activities of the C&D Working Group. The C & D Working Group is composed of:

- Recyclers' industry represented by:
  - All Earth Group, Maddington
  - Capital Demolition, Bayswater, and
  - C&D Recycling, Hazelmere.
- Users of recycled C&D materials:
  - Local Government representatives (Canning, Mandurah, Kwinana, Nedlands), and
  - State Government departments and authorities – Department of Environment and Conservation, Main Roads Western Australia, Waste Management Authority.
- Consultants to waste industry and Local Government, and
- Western Australian Local Government Association.

The aim of the C&D Working Group is to:

- Reduce the volume of C&D waste to landfill with environmental and financial efficiency;
- Promote use of recycled products to business and government;
- Educate industry and government on benefits of recycling;
- Provide a cohesive balanced group as a reference point for industry and government.

Colin Leek presented a detailed review of the Welshpool Rd. demonstration project, where recycled materials were used for the construction of a heavy trafficked road. It was noted that this was a demonstration project, as the use of recycled demolition materials for pavement construction has been well established in the eastern states of Australia and overseas for many years.

Four different pavements were constructed:

- 250 mm commingled recycled subbase with 150 mm new roadbase
- 400 mm commingled recycled base
- 250 mm 50 mm commingled recycled subbase with 150 mm recycled concrete only base, and
- 400 mm recycled concrete only base.

It was advised that significant testing had been undertaken using Repeat Load Triaxial testing, Falling Weight Deflectometer testing, Shear Box testing as well as routine grading and plasticity limits.

It was reported that the structural testing indicated that recycled materials performed equally, if not better than virgin quarried products, and that the materials were easily worked, and withstood the effects of turning traffic exceedingly well.

There were significant cost savings both in materials and transport, and the ability to backload roadbase when disposing of boxout material was of considerable benefit, both economically and environmentally.

A.2 Survey results

Following the workshop, a survey was undertaken to determine the factors that either work towards or against the use of recycled products. Surveys were sent to 96 persons, 29 people responded (30%). The response, however, was sufficient to obtain some useful data. The results are shown in Table A. 3.

In some questions, there was a large number of 'NC' entries which means that persons did not give an answer.

An analysis of the survey results is presented in the following sections.

Table A. 3: Results of recycled products workshop survey

Question	**No. of Replies**	**29**	**No. Sent**	**92**
Workshop Objectives	Yes	No	NC	Average score out of 5
Although registered, did you attend the workshop	27	2	0	
Did you find the workshop gave information that was useful to you or your organisation?	27	0	2	3.3
How would you rate the workshop in general				4.0
Prior to attending the workshop, would you have considered using recycled products if they were offered to you for a road project?	22	4	3	
Following the workshop, have you now changed your view on recycled products in roadworks?	10	16	3	
Environmental Considerations				
Considering the following criteria, please rate the importance of various benefits of using recycled products:				
Saving on landfill space				4.5
Saving on energy use				4.1
Reduction of greenhouse gas emissions				4.2
Conservation of resources				4.4
Reduced habitat loss				4.0
Reuse of materials because it makes sense				4.6
Cost Considerations (Based on delivered price)				
Considering the following cost implications, please answer the following:				
I would use recycled materials only if they were cost neutral	14	10	5	
I would use recycled materials only if they were cheaper than new materials	10	13	6	
I would use recycled materials even if they cost more than new materials	18	6	5	
If you would pay more, what percent more would you consider reasonable	0	1	12	
Technical Considerations				
Considering the following performance criteria, please indicate your level of confidence:				
How confident are you in the performance of recycled products				3.9
How confident are you in the quality control of recycled products				3.7
At the present time would you reject using recycled products due to performance or quality concerns?	6	17	10	Ignore
Are you that recycled materials can be supplied in sufficient quantities?	17	10	2	
Balanced cost implications				
Considering the way you currently do business:				
Do you currently consider supply tenders or quotes on cost only?	6	18	5	
If you answered No above, which of the following factors do you currently consider?				

	Energy use				
	Greenhouse gas emissions	5	7	17	
	Conservation of resources	7	5	17	
	Other (Please insert in comments section)				
Considering the way you will do your future business:					
	Following the workshop, will you change the way you assess tenders?	14	4	10	
	If you answered Yes above, which of the following factors would you include as selection criteria				
	Energy used in production	11	3	15	
	Transport energy usage	13	2	14	
	Total greenhouse emissions	10	4	15	
	Use of recycled materials	17	0	12	
	Commitment to research and development	12	1	16	
	Other (Please insert in comments section)				

Considering the case studies presented, would you consider using the following products in road construction? If Yes, please rate how confident you are for each use?					
Recycled pure crushed concrete					
	Subbase in light traffic roads	23	0	16	4.1
	Subbase in heavy traffic roads	21	2	16	3.9
	Base in light traffic roads	21	2	16	3.5
	Base in heavy traffic roads	17	5	18	3.0
Recycled commingled demolition materials (concrete with brick, asphalt, tiles)					
	Subbase in light traffic roads	23	1	15	3.8
	Subbase in heavy traffic roads	18	4	19	3.4
	Base in light traffic roads	19	3	20	3.2
	Base in heavy traffic roads	15	8	19	2.7
Recycled crushed glass					
	As part aggregate replacement in asphalt	22	2	16	4.1
	As part aggregate in subbase	18	6	17	3.6
	As part aggregate in base	15	8	17	3.3
Recycled crumbed rubber					
	As binder supplement in hot bitumen	21	3	17	3.4
	Added to aggregate in asphalt plant	21	3	17	3.4
Considering the case studies presented, would you consider using the following products in concrete for footpaths?					
	Recycled crushed demolition materials	26	0	15	3.8
	Recycled crushed glass	25	1	15	3.9
Landfill Operations					
Considering landfill operations, please answer the following:					
	Do you consider a landfill levy as being a good way of diverting products from landfill?	20	6	3	
	Do you think a levy should be a flat rate for all materials?	1	24	3	
	Do you think a levy should be higher for products that can be easily recycled?	20	5	4	
	Do you think a levy should be lower for products that are difficult or cannot be recycled?	16	8	5	
	Have you noticed a relationship between landfill costs and illegal dumping?	13	8	8	
	Do you think that regulation to prevent recyclables being landfilled is desirable?	23	4	2	
Further Information (If answer is yes, please include contact details below)					
	Would you like to receive any follow up information subsequent to the workshop	24	5	0	
	Would you like to receive information from Western Australian Local Government Association on specification clauses and selection criteria	24	4	0	
	Would you like to receive relevant on-going information from the C&D Woking Group	27	2	0	
	Would they like to inspect a C&D Recycling facility.	14	15	0	
	Would you like a free truck load of recycled material to experiment with	6	21	1	

A.2.1 Workshop objectives

On the question of workshop objectives, of the 29 responses, 27 felt that they received useful information, and the workshop received a rating of 4 out of 5.

As expected, due to the fact that those attending were likely to be committed to recycling, a large proportion would have considered using recycled products prior to the workshop, only 4 of 29 indicated they would not.

With regard to the survey question, ‘Following the workshop, have you changed your view on recycled products in roadworks?’, it would appear that either the question was not understood, or people have gained or lost confidence in recycled products.

Looking at the individual returns, all those who said they would not consider use of recycled products did indeed change their mind after the workshop. There were no cases where someone changed their mind against use of recycled products.

Survey results for workshop objectives are detailed in Table A. 4.

Table A. 4: Survey results for workshop objectives

Workshop objectives	Yes	No	NC	Average score out of 5
Although registered, did you attend the workshop?	27	2	0	
Did you find the workshop gave information that was useful to you or your organisation?	27	0	2	3.3
How would you rate the workshop in general?				4.0
Prior to attending the workshop, would you have considered using recycled products if they were offered to you for a road project?	22	4	3	
Following the workshop, have you now changed your view on recycled products in roadworks?	10	16	3	

A.2.2 Environmental considerations

All environmental issues, such as saving on landfill space, energy, greenhouse gas emissions, conservation of resources, habitat loss and reusing materials all rated between 4 and 5, indicating that all of these are priority items to those attending the workshop.

Survey results for environmental considerations are detailed in Table A. 5.

Table A. 5: Survey results for environmental considerations

Environmental considerations	Yes	No	NC	Average score out of 5
Considering the following criteria, please rate the importance of various benefits of using recycled products:				
Saving on landfill space				4.5
Saving on energy use				4.1
Reduction of greenhouse gas emissions				4.2

Conservation of resources				4.4
Reduced habitat loss				4.0
Reuse of materials because it makes sense				4.6

A.2.3 Cost considerations

In order to determine the effect cost had on the reuse of recycled products, respondents were asked to indicate whether they would use recycled products only if they were cheaper, cost neutral, or whether they would indeed pay more.

The results indicated that 43% would be prepared to pay more to use recycled products, 33% would only use them if they were cost neutral, and 24% if they were cheaper.

Of those prepared to pay more, the amount extra they would pay ranged from 2% to 30% with the average being 14%. The 90^{th} percentile value was 5%.

Survey results for cost considerations are detailed in Table A. 6.

Table A. 6: Survey results for cost considerations

Cost considerations (based on delivered price)	Yes	No	NC	Average score out of 5
Considering the following cost implications, please answer the following:				
I would use recycled materials only if they were cost neutral	14	10	5	
I would use recycled materials only if they were cheaper than new materials	10	13	6	
I would use recycled materials even if they cost more than new materials	18	6	5	
If you would pay more, what percent more would you consider reasonable?	0	1	12	

A.2.4 Technical Considerations

Questions were asked to gauge the confidence people have in recycled products. There is a reasonable level of confidence (3.9 out of 5) in the performance of recycled products, but a slightly lesser confidence (3.7 out of 5) in the quality control of recycled products.

Due to the structure of the questionnaire, the answer to ‘At the present time, would you reject the use of recycled products due to performance or quality issues?’ was unclear, and some interpretation of each answer was necessary. Those who would at present reject the use of recycled material on quality grounds were in the minority. Survey results for technical considerations are detailed in Table A. 7

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Table A. 7: Survey results for technical considerations

Technical Considerations	Yes	No	NC	Average score out of 5
Considering the following performance criteria, please indicate your level of confidence:				
How confident are you in the performance of recycled products				3.9
How confident are you in the quality control of recycled products				3.7
At the present time would you reject using recycled products due to performance or quality concerns?	6	17	10	
Are you sure that recycled materials can be supplied in sufficient quantities?	17	10	2	

(Note figures in red are due to concern that the question was misunderstood)

A.2.5 Balanced cost considerations

Questions were asked to ascertain how organisations currently assess tenders and quotations for services and products, and whether after the workshop, they would consider other costs related to environmental and social aspects of producing that product. There were few responses, and this may be due to the fact that only a small number of respondents have a purchasing responsibility in their current position.

It was noted that under current purchasing guidelines, only 6 respondents indicated that they used price as their only assessment criteria, whereas 18 respondents indicated that considerations other than tender price were considered.

Of those that do have assessment criteria, only a very small number consider greenhouse gas emissions and conservation of resources in their assessment process. No respondent indicated that energy consumption itself was considered, although some may consider this an aspect of greenhouse.

Following the workshop, however, a clear majority indicated that they would assess tenders on a different basis in the future, and look at other environmental factors as well as the normal cost, service and experience considerations.

Of those who answered in the positive for environmental issues, most indicated that they would include use of recycled materials in their assessment process. Energy used in transport rated next, but this could in fact be a direct price consideration as well. The use of energy and production of greenhouse gases were also important issues given the numbers responding positively.

Survey results for environmental considerations in tender assessments are detailed in Table A. 8

Table A. 8: Survey results for tender assessment criteria

Balanced cost implications	Yes	No	NC	Average score out of 5
Considering the way you currently do business:				
Do you currently consider supply tenders or quotes on cost only?	6	18	5	
If you answered No above, which of the following factors do you currently consider?				
Energy use				
Greenhouse gas emissions	5	7	17	
Conservation of resources	7	5	17	

Balanced cost implications	Yes	No	NC	Average score out of 5
Considering the way you will do your future business:				
Following the workshop, will you change the way you assess tenders?	14	4	10	
If you answered Yes above, which of the following factors would you include as selection criteria				
Energy used in production	11	3	15	
Transport energy usage	13	2	14	
Total greenhouse emissions	10	4	15	
Use of recycled materials	17	0	12	
Commitment to research and development	12	1	16	

A.2.6 Use of recycled products in construction

A large number of 'no comments' were received, and it is suggested that this is due to the fact that a number of respondents were not in a position where they can influence the use of materials.

The balance between the yes and no answers in the questionnaire, however, is highly favourable to the selection of recycled products in road construction. It does appear, however, despite the information given about Welshpool Road, that there is a slightly higher degree of confidence in pure recycled concrete as a substitute material than recycled commingled demolition materials. Survey results for use of recycled products in road construction are shown in Table A. 9.

Table A. 9: Use of recycled products in road construction

Use of recycled products in construction activities	Yes	No	NC	Average score out of 5
Considering the case studies presented, would you consider using the following products in road construction? If Yes, please rate how confident you are for each use?				
Recycled pure crushed concrete				
Subbase in light traffic roads	23	0	16	4.1
Subbase in heavy traffic roads	21	2	16	3.9
Base in light traffic roads	21	2	16	3.5
Base in heavy traffic roads	17	5	18	3.0
Recycled commingled demolition materials (concrete with brick, asphalt, tiles)				
Subbase in light traffic roads	23	1	15	3.8
Subbase in heavy traffic roads	18	4	19	3.4
Base in light traffic roads	19	3	20	3.2
Base in heavy traffic roads	15	8	19	2.7

Use of recycled products in construction activities	**Yes**	**No**	**NC**	**Average score out of 5**
Considering the case studies presented, would you consider using the following products in road construction? If Yes, please rate how confident you are for each use?				
Recycled crushed glass				
As part aggregate replacement in asphalt	22	2	16	4.1
As part aggregate in subbase	18	6	17	3.6
As part aggregate in base	15	8	17	3.3
Recycled crumbed rubber				
As binder supplement in hot bitumen	21	3	17	3.4
Added to aggregate in asphalt plant	21	3	17	3.4
Considering the case studies presented, would you consider using the following products in concrete for footpaths?				
Recycled crushed demolition materials	26	0	15	3.8
Recycled crushed glass	25	1	15	3.9

As would be expected, the confidence level is inversely related to the road hierarchy, and is higher for use as a subbase than as a base. The use of glass as an aggregate replacement in asphalt was rated with more confidence than as an aggregate replacement in subbase and base materials.

There was also a high confidence expressed for the use of crumb rubber in asphalt, and for the use of crushed glass and recycled demolition materials in low use concrete for footpaths and kerbs.

A.2.7 Landfill levy

Participants were asked about how they saw the operations of the current landfill levy. Unfortunately, the question as to whether the current landfill levy was considered reasonable was not asked.

It is clear, however, that a landfill levy is supported, but that it should be higher for those products that are easily recyclable. There does seem also to be some agreement that a higher levy or costs will lead to a greater degree of illegal dumping. A very clear majority of respondents agree that regulation to prevent recyclable products from being dumped in landfill is desirable.

Survey results for the landfill levy questions are detailed in Table A. 10.

Table A. 10: Survey results for landfill levy

Landfill operations	Yes	No	NC	Average score out of 5
Considering landfill operations, please answer the following:				
Do you consider a landfill levy as being a good way of diverting products from landfill?	20	6	3	
Do you think a levy should be a flat rate for all materials?	1	24	3	

Do you think a levy should be higher for products that can be easily recycled?	20	5	4	
Do you think a levy should be lower for products that are difficult or cannot be recycled?	16	8	5	
Have you noticed a relationship between landfill costs and illegal dumping?	13	8	8	
Do you think that regulation to prevent recyclables being landfilled is desirable?	23	4	2	

A.3 Comments on workshop

The outcomes of the workshop survey are encouraging, the number of attendees indicating the interest in Local Government to use recycled products in road construction activities. The feedback from the survey provides some useful insights into perception of recycled construction material.

APPENDIX B MRWA SPECIFICATION 501.94

501.94 CRUSHED RECYCLED CONCRETE BASECOURSE

501.94.01 GENERAL

1. The material shall consist of a uniformly blended mixture of coarse and fine aggregate resulting from the crushing of recycled concrete from construction and demolition waste. ***General***

2. Coarse aggregate (retained on 4.75mm sieve) shall consist of hard durable angular fragments and shall not break up after wetting and drying. Foreign material content shall be limited to the values shown in Table 501.23. ***Foreign Material***

3. Fine aggregate (passing 4.75mm sieve) shall consist of crushed material or crushed material and sand with similar durability properties to that of the coarse aggregate.

TABLE 501.23 LIMITS OF FOREIGN MATERIAL

Material	Maximum % Retained by Mass on 4.75mm Sieve
High Density Materials (brick, glass, etc.)	10
Low Density Materials (plastic, plaster, etc.)	2
Wood and other vegetable matter	0.5
Asbestos	0

501.94.02 PARTICLE SIZE DISTRIBUTION

1. The particle size distribution shall be determined in accordance with Test Method WA 115.1 and shall conform to the limits shown in 501.24. The grading of material passing the 26.5mm sieve shall vary from coarse to fine in a uniform and consistent manner. The material shall not be gap graded as represented by the grading crossing from the maximum limit for one sieve size to the minimum limit for another sieve size, and shall conform as closely as possible to the specified target grading. ***Particle Size Distribution***

TABLE 501.24 PARTICLE SIZE DISTRIBUTION (CRUSHED RECYCLED CONCRETE FOR BASECOURSE)

AS 1152 Sieve Size (mm)	% Passing by Mass Target Grading	% Passing by Mass Minimum and Maximum Limits
26.5	100	100
19.0	100	95 – 100
9.5	70	59 – 80
4.75	50	41 – 60
2.36	37	29 – 45
1.18	26	20 – 35
0.600	19	13 – 27
0.425	16	10 – 23
0.300	13	8 – 20
0.150	10	5 – 14
0.075	8	3 – 11

501.94.03 OTHER ACCEPTANCE LIMITS

1. The material shall also conform to the following limits shown in Table 501.25.

Other Acceptance Limits

TABLE 501.25 ACCEPTANCE LIMITS (CRUSHED RECYCLED CONCRETE BASECOURSE)

(Suitable for design traffic <5x10^6ESA)

Test	Requirement	Test Method
Liquid limit	35.0% Maximum	WA 120.2
Linear Shrinkage	3.0% Maximum	WA 123.1
LA Abrasion	40% Maximum	WA 220.1
Maximum Dry Compressive Strength	1.7MPa Minimum	WA 140.1
California Bearing Ratio (Soaked 4 days) at 98% of MDD and 100% of OMC	100% Minimum	WA 141.1
Unconfined Compressive Strength (UCS- 7 days cured and 4 hours immersed)	1.0MPa Maximum	WA 143.1

501.94.04 STOCKPILING AND MOISTURE CONTENT

Stockpiling & Moisture Content

1. Crushed recycled concrete basecourse material shall be pre-wet to greater than 95% of the optimum moisture content as determined from Test Method WA 133.1 or WA 133.2 as appropriate. The moisture content shall be determined in accordance with Test Method WA 110.1.

2. Crushed recycled concrete basecourse material and water shall be thoroughly mixed using a pugmill or any other alternative method approved by the Superintendent to produce a homogeneous product suitable for placement in the final position.