Recycling

Cost analysis and energy balance

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Recycling domestic refuse in the Perth metropolitan area is an economically feasible and energy efficient proposition.

Around half a million tonnes of domestic refuse is generated annually throughout the Perth metropolitan area, the majority of the refuse being landfilled. Consequently, $12 million to $16 million of secondary resources are lost from the economy, a further 20 petajoules of energy being wasted, equivalent to the energy that would be used annually by 1.5 million Perth homes.

A 95% energy saving is derived from recycling aluminium cans, a 50% energy saving from remelting waste or broken glass, with an 85% energy saving from reusing glass containers and bottles, than producing comparative products from raw materials. There is a 45% energy saving by recycling polyethylene and polypropylene, 40% saving by recycling polyvinylchloride and polystyrene, and 40% energy saving from recycling polyethylene terephthalate, with a further 68% energy saving by recycling paper pulp.

The separation of domestic refuse at the source of generation by householder participation eliminates the need for expensive, and often ineffective, mechanical separation and sorting equipment. By providing each dwelling with a suitable receptacle, or receptacles, for placing recycling materials in, the residents need not be involved with messy and time consuming manual separation processes, but rather separate and discard the refuse into the appropriate receptacle as the refuse is generated.

The cost of collecting recycling materials is met by the revenue generated from their sale when the participation rate from the collection round is 30% to 40%, a reasonable goal to be achieved within the first two years of operation.

The recycling contractor may need to be initially subsidised on a per house basis until such time as the break even point is attained. It is possible for the local council to subsidise a recycling collection, without financially disadvantaging ratepayers by contributing the savings from lower tonnages being disposed of by landfill.

In order to service the entire Perth metropolitan area with a fortnightly collection of recycling materials, a capital outlay in the range of $4 million to $10 million would be required. In addition to this, an annual expenditure of between $2 million and $5.5 million would pay for the ongoing operation of all schemes whilst providing employment for 200 unskilled workers and 50 semi-skilled workers.

There are six major components to the establishment, implementation and operation of separation at source door-to-door recycling schemes, as summarised below.

1. Local Government initiates the implementation of a recycling programme to establish regular and frequent door to door collections of recyclable materials:

- contract the collection of all recyclable materials;
- promotion of scheme and education;
- provision of receptacle to all dwellings; and
- further education and promotion.

2. Separation at source of all recyclable materials implemented.

3. Collection of recyclables by contractor.

4. Further separation at depot into following streams:

- cans and tins
  - — aluminium
  - steel
  - bimetallic, jars
- glass bottles and containers
  - refillable bottles
  - non-refillable bottles and containers
  - colour sorted glass

- paper
  - newsprint
  - print (high) quality
  - magazines
  - cardboard
- plastic
  - polyethylene: high density containers, bags — low density bags and film
  - PET: soft drink bottles
  - polyvinylchloride: bottles, containers, film
  - polystyrene: bottles, containers, food and produce trays
  - polypropylene: bottles, containers
- rags, cloth, and clothing
- other recyclable materials, including car batteries, used motor oil, solvents

5. Collection by industry, or transport to industry.
6. Industry processes material for recycling.

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Peet Fremantle

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1. Introduction

Perth metropolitan households generate around 500000 tonnes of domestic refuse annually, and all but a small proportion of this will find its way into sanitary landfill. Landfill, once thought to be the best way of getting rid of domestic refuse whilst eliminating the inconvenience of low-lying waste lands, has since become increasingly associated with groundwater pollution, and the harbouring of organisms capable of causing and spreading disease and infection.

More recently, landfill sites have been highlighted as an active source of greenhouse gases. For every tonne of domestic refuse that goes into sanitary landfill, it is estimated that 400m^3 of landfill gas is generated. This gas consists mainly of methane and carbon dioxide, with methane being 27 times more active as a greenhouse gas than carbon dioxide.

Appropriate sites suitable for the landfilling of domestic waste are fast diminishing, not only due to environmental regulations, but also due to the negative aesthetic appeal of this land use being located near residential homes. The rationalisation of waste management by the Health Department will result in fewer landfill sites being located on the Swan Coastal Plain area. As local councils are forced to look further away from the source of refuse generation for suitable sites, it will become apparent that there is a need to consider alternative waste management options, primarily to reduce their expenditure on disposal and transport.

It is already rare to find a municipality that can currently provide a weekly collection service for less than $10 per tonne of refuse collected. More often than not, the cost to the local council and ratepayer is around $50 per tonne for collection and disposal. Therefore, it is expected that the charge to ratepayers for future refuse collection and disposal will continue to increase as landfill sites are located further away.

It is also reasonable to expect that the municipalities with control over the few remaining landfill sites, will set charges reflecting the importance of the service to dependent municipalities, and to contribute towards the ongoing management and monitoring of the landfill site, and establishing future sites.

With the increasing awareness of the Greenhouse Effect and the need to conserve non-renewable natural resources, the community is embracing recycling in a favourable way. Individuals and community groups have started to separate their waste into various recycling streams, yet they are hindered by the lack of provision of efficient, regular and reliable collection services for recycling materials. Greenline, an information service on practical ways to help the environment operating within the Environmental Protection Authority, is receiving a minimum of 70 enquiries per week from residents in the Perth metropolitan area wanting to know where their closest recycling centre is because they are not receiving a home collection service. The Environmental Protection Authority is supporting and encouraging local government throughout the Perth metropolitan area to offer and implement recycling collection services for all residents and premises.

In the past, most local councils within the Perth metropolitan area have approached the idea of recycling domestic refuse with a high degree of scepticism. Whilst recognising the up front and short-term cost of implementing recycling collections, local councils have generally, overlooked the long-term economic and environmental benefits from recycling, and the desire of their ratepayers to be actively participating in a separation at source door-to-door recycling collection scheme. Taking into account the community's desire to recycle and the apprehension felt by local government to provide an adequate collection service, the Environmental Protection Authority has conducted this study to determine the economic feasibility of recovering and recycling the inorganics and plastic in the weekly domestic waste stream, and to estimate the resultant energy saving for this State.

The cost analysis sets out the major areas of expenditure for offering and operating a collection and recycling scheme, in terms of the initial capital expenditure and the ongoing weekly operational expenditure. Within this scope, various alternatives have been considered, regarding the type of equipment being utilised, the number of people employed per scheme, and the frequency of collection being offered. It has been assumed that there are 5000 dwellings per collection round, with a distribution reflective of the established residential areas within the Perth metropolitan area (excluding multiple unit residences of five or more dwellings). Weekly and fortnightly collection frequencies have been considered.

The energy balance is a comparative study of the energy that goes into producing a material from raw material resources, and recyclable materials separated from the domestic waste stream. The comparison investigates the case for aluminium cans, refillable and non-refillable glass containers and bottles, unbleached and bleached paper products, polyethylene (PE) products, polyethylene terephthalate (PET) beverage containers, polypropylene (PP), polystyrene (PS), and polyvinylchloride (PVC) products. The energy balance is based on data from Western Australian industry where possible. In some instances, certain stages of material processing and recycling are not presently available in Western Australia, so the relevant interstate or international industry figures are cited.

Waste is not waste if it has a value. Currently, the refuse disposed of annually throughout the Perth metropolitan area has a market value in the range of $12 million to $16 million as secondary resources. If the refuse with an economic value is separated from the waste destined for landfill, then a further saving in the range of $2 million to $5.5 million is derived from reducing the tonnage of waste going into landfill.

Capital intensive separating and processing plants are not the answer to obtaining inorganic, organic and plastic waste streams. Community participation in source separation schemes for domestic refuse with door-to-door collection of the glass, paper, metals and plastics, is a reasonably easy and practicable way to provide industry with secondary resources in the quality they desire, and to obtain an almost pure organic waste ready for composting within a low technology plant.

Organic waste can be composted into an efficient soil conditioner, for lawns and gardens, to improve the water retention capacity of the soil. The Perth metropolitan area, being located on a sandy coastal plain, and facing the risk of having less water in coming years due to global warming, will find the use of a soil conditioner invaluable.

2. The recycling scheme

Two feasible options exist for the operation of a separation at source door-to-door collection service for materials suitable for recycling.

The first option is for each local council to operate the collection as part of the normal municipal collection. Some local councils have attempted to operate recycling schemes of this nature, but have limited the collection to glass beverage bottles, paper, and aluminium cans. Where this type of partial recycling scheme has been introduced, the participation rate does not usually exceed 40%, with the tonnage of material collected being far less than what could be reasonably expected. Consequently, most councils have found it to be too expensive to continue this type of scheme. This emphasises the need for a recycling scheme to offer the capacity to collect all materials from domestic refuse that are suitable for recycling, not only to make it easy for the participants to cooperate, but to maximise the energy efficiency and cost effectiveness of the entire scheme.

Alternatively, the second option is for the council to tender the operation of the scheme to private contractors, whether they are traditional recycling groups, Marine Collectors, charity organisations or a new party entering the field of recycling. The tenderer should have full responsibility for all facets of the collection, separation and selling of the recyclable material to industry.

Contractual arrangements may be required, between the council and tenderer, to ensure that the collection service is frequent, reliable and effective in meeting its objectives. The arrangement may be required to extend into financial assistance during the initial stages of operation, depending on the tonnage of waste generated per dwelling, the tonnage that is collected per dwelling, and the participation rate per collection round.

In the event of a financial agreement being entered into by a local council and contractor, it is expected that the contractor would submit regular audits to the appropriate council, setting out the total tonnage of material being collected, with a breakdown of this total tonnage into the type of material, such as newsprint, cardboard, returnable bottles, and the like. Further more, an estimate of the average participation rate of dwellings, and the rate at which collection containers are being lost or damaged, and hence requiring replacement, and requests from larger residences requiring additional containers, should be included.

It is important to note here that the amount of domestic refuse generated per week, in the Perth metropolitan area, varies between 10 and 30 kilograms per dwelling, depending primarily on the number of inhabitants per dwelling, and their age distribution. Approximately 50% of this refuse can be recycled through the proposed scheme. Other factors influencing this amount of refuse generated includes the current economic condition, the location of the dwelling and municipality, and the season of the year (Ho, 1983).

Each local council is best able to investigate or analyse the patterns of domestic refuse generation within their own municipality. Most councils to date, have rough estimates of the annual mass of refuse collected, very few having conducted accurate studies or investigations into the nature of refuse generation within their municipality. The cost analysis takes into account the variations inherent between municipalities.

To attract or encourage the greatest participation rate possible, the recycling scheme needs to be reliable and frequent, but above all convenient and easy for residents to participate. The cost analysis shows the cost efficiency of operating collection schemes on a weekly and fortnightly basis.

Current schemes operating on a monthly basis do not adequately meet the needs of the community it services. Householders must have room to store paper, bottles and cans, and then shift the weighty bulk of this material out to a suitable position near the front of the property. The inconvenience of this exercise, and the lengthy period between collections ensures that only the dedicated participate regularly and to capacity.

Whilst weekly collections of recycling material are preferable in meeting the objectives of the scheme, fortnightly collections reduce expenses on a per week basis relative to a weekly service. Therefore, from the operator's point of view, it is preferable to initially establish fortnightly collections. The frequency of collection can be increased at a later date to correspond with an increase in the participation rate or the demand for a more frequent service from participants.

It is also possible with the fortnightly collection scheme to extend the collection to two rounds, or 10000 dwellings, utilising a single collection vehicle, and a two or three person collection crew. By collecting from each round on alternate weeks, the operational expense is the same as that for a weekly collection of one round, but the amount of recycling material collected could be effectively doubled. For example, assuming that each dwelling generates, on average, 20 kilograms of solid refuse per week, then approximately 40 kilograms are generated per fortnight.

If the collection scheme is reliable and the promotion and education for the scheme has been effective, then each dwelling is likely to separate between 70% and 100% of their recycling materials each week. Therefore, between 14 and 20 kilograms of recycling material could be collected from each dwelling every fortnight, for recycling.

3. Cost analysis

3.1 Cost of establishing a recycling collection scheme

To establish the means of providing a bag type collection scheme servicing one collection round of 5000 dwellings, an initial capital expenditure between $79000 and $123000 would allow for the purchase of land for siting the collection and separation depot, a one to three tonne collection truck, a forklift to move larger containers around the depot and to off-load the collection truck, sufficient collection bags to operate an exchange system on the day of collection for each dwelling within the collection round, and a Marine Dealer's Licence.

Table 1a provides a general breakdown of the expense involved in establishing this type of recycling scheme. Land prices quoted are for $1000m^3$ of light industrial land within the Perth metropolitan area (June, 1990). The prices include an on-site shed which will provide office space and some under cover storage.

Should the operator have ready access to this type of land, and a suitable truck to operate the collection, then the initial outlay can be reduced to between $9000 and $24000 for a bag collection scheme.

It is necessary for the operator of the recycling scheme to obtain a Marine Dealer's Licence under the Marine Stores Act, 1902. This allows for the collection and selling of all materials suitable for recycling, as discussed within this paper.

		Lease or rent	Purchase	Minimum cost expected	Maximum cost expected
Land (with shed)		$45 to $50 per m^2	$78 to $85 per m^2	$45000 (1000$m^2$)	$85000 (1000$m^2$)
Collection vehicle (1 to 3 tonne)	new		$25000	$25000	
	used		$29000		$29000
Forklift (1 to 3 tonne)	new	$250 per month	$17000	$3000	$18000
	used		$18000		
Collection containers	bags	$0.60 each	$6000	$6000	
	cartons	$1.50 each	$9000		
	crates	$8.00 each	$40000		$40000

Table 1a: Capital expenditure in providing a recycling collection scheme

	System	Total cost	Land and vehicle supplied
1	Bags	$79000 to $123000	$9000 to $24000
2	Cartons	$82000 to $126000	$12000 to $27000
3	Crates	$113000 to $157000	$43000 to $58000

Table 1b: Estimated capital cost

3.2 Cost of operating a recycling collection scheme

The average weekly expenditure incurred by a contractor for operating a door to door collection service, varies between 9 cents and 27 cents per dwelling per week. The variation in this cost depends primarily on the frequency of the collection, and the number of employees per recycling scheme. Approximately 70% of the cost can be attributed to wages for the sorting and collection crew employees. It is assumed that employees are averaging 25 hours working time per week and paid at a rate equivalent to the Municipal Employees (WA) Award.

For a weekly collection scheme (four employees) the average weekly cost for operating the scheme is 18 to 23 cents per dwelling, whilst for a fortnightly collection scheme (one round) this is reduced to between 12 and 15 cents per dwelling per week.

If the collection scheme was to operate with five employees, then an additional 2 cents per dwelling per week would be required to meet the increased weekly expenditure.

Schemes have been successfully run with only three people involved in the collection and sorting processes. Under these conditions, expected costs of operation are in the range of 9 to 14 cents per week, and therefore the annual cost to the council or ratepayer is between $5 and $8.

Table 2 is a summary of the weekly expenditure per collection scheme, given as the cost per dwelling per week, and the cost per dwelling per year, for schemes employing three, four and five people. For schemes employing four or five people, it has been assumed that two and three employees, respectively, are in the age bracket of 16 to 18 years.

Operating costs	Three employees	Four employees	Five employees
Weekly collection (5000 dwellings)			
Total cost per week	$870.00 - $1090.00	$890.00 - $1120.00	$1030.00 - $1330.00
per dwelling per collection	$0.18 - $0.22	$0.18 - $0.23	$0.21 - $0.27
per dwelling per year	$10.00 - $12.00	$10.00 - $12.00	$11.00 - $14.00
Fortnightly collection (5000 dwellings)			
Total cost per week	$560.00 - $710.00	$570.00 - $730.00	$660.00 - $860.00
per dwelling per collection	$0.24 - $0.28	$0.24 - $0.30	$0.26 - $0.34
dwelling per year	$7.00 - $8.00	$7.00 - $8.00	$7.00 - $11.00
Fortnightly collection (10000 dwellings)			
Total cost per week	$870.00 - $1090.00	$890.00 - $1 120.00	$1030.00 - $1330.00
per dwelling per collection	$0.09 - $0.11	$0.09 - $0.11	$0.11 - $0.13
per dwelling per year	$3.00	$3.00	$3.00 - $4.00

Table 2: Cost of operating a recycling collection scheme

For collection rounds in municipalities that average 10 kilograms per week generation of domestic refuse per dwelling, then a 30% to 40% participation rate of dwellings is required for the operator to reach the break even point for weekly collections of one round. At 20 kilograms per week generation of domestic refuse, the participation rate required is between 20% and 30%. Given the current attitude and feeling of the community toward recycling, it is reasonable to expect that this point is achieved within 24 months of regular operation.

A 20% to 30% participation rate is required to reach the break-even point for a fortnightly collection scheme for one round. The alternative fortnightly scheme of collection from two rounds on alternate weeks, could achieve break even with a 20% participation rate. A summary of the break even points for various rates of refuse generation is given in Table 3. This is based on the current rate of payment to contractors and fund raising groups.

	Participation rate				
	Recycling contractor			Fund raising organisation	
Average rate of refuse generation per home	Three employees per scheme	Four employees per scheme	Five employees per scheme	One employees per scheme	Two employees per scheme
Weekly collection (5000 dwellings)					
5kg per dwelling	60 - 70%	70 - 80%	80 - 90%	80 - 90%	(not viable)
10kg per dwelling	30 - 40%	30 - 40%	40 - 50%	40 - 50%	60 - 70%
15kg per dwelling	20 - 30%	20 - 30%	30 - 40%	30 - 40%	40 - 50%
20kg per dwelling	20 - 30%	20 - 30%	30 - 40%	20 - 30%	30%
Fortnightly collection (5000 dwellings)					
10kg per dwelling	30 - 40%	30 - 40%	50 - 60%	30 - 40%	50 - 60%
15kg per dwelling	20 - 30%	20 - 30%	20 - 30%	30%	30 - 40%
20kg per dwelling	20 - 30%	20 - 30%	20 - 30%	20 - 30%	30%
30kg per dwelling	10 - 20%	10 - 20%	10 - 20%	20%	20 - 30
Fortnightly collection (10000 dwellings)					
10kg per dwelling	20 - 30%	20 - 30%	30 - 40%	40 - 50%	60 - 70%
15kg per dwelling	20 - 30%	20 - 30%	20 - 30%	30 - 40%	40 - 50%
20kg per dwelling	10 - 20%	10 - 20%	10 - 20%	20 - 30%	30%
30kg per dwelling	10%	10%	10%	20%	20 - 30%

Table 3: Summary of the participation rates required to achieve the break even point depending on the rate of refuse generation

It is important to note here that several companies have guaranteed minimum payment prices for the next 12 to 24 months. The relevant companies and prices are as follows:

Material	Company with guarantee	Minimum price guarantee
Newspaper	Green Recycling	$30 to $35 per tonne
Aluminium cans	Comalco	$700 per tonne
PET soft drink bottles	ACI Plastics Packaging	$700 per tonne
Glass	Australian Glass Manufacturers	$45 per tonne-colour mixed glass $55 per tonne-colour sorted glass

4. Energy balance

The energy required to recover and recycle aluminium, glass, paper, polyethylene (PE), polyethylene terephthalate (PET soft drink bottles), polypropylene (PP), polystyrene (PS) and polyvinylchloride (PVC) from domestic refuse, is considerably less than the energy required to produce these materials from raw materials, particularly when the refuse is separated at source, and collected regularly and frequently from this source.

The energy requirements for producing these material, from raw materials and recyclable materials separated from domestic refuse, has been calculated in terms of gigajoules per tonne of material. For perspective, a typical Perth householder uses on average, 13 gigajoules of energy per year at home.

Calculations relating to the energy requirement are based on the conditions applicable to industries within Western Australia. Where some stages of processing or recycling are not available in Western Australia, then the appropriate interstate or international figures are quoted. The additional energy required to transport the material between sites is therefore included.

Figure 1 shows the variation of energy that goes into producing one tonne of aluminium, glass, unbleached and bleached paper, polyethylene, polyethylene terephthalate, polypropylene, polystyrene, and polyvinylchloride, from raw materials, and recyclable materials recovered from domestic refuse and collected through a separation at source collection service.

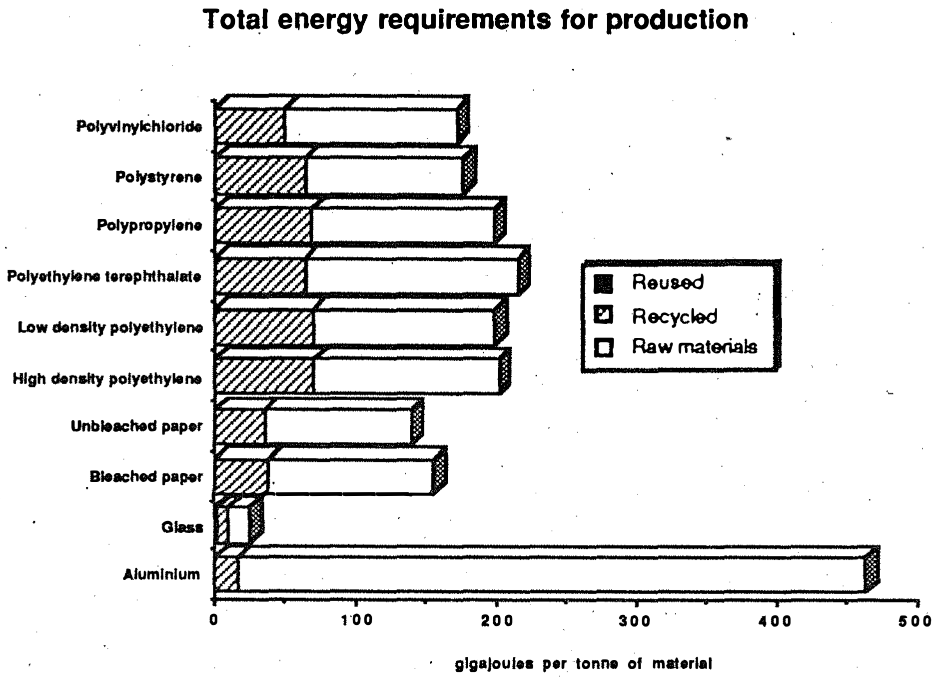

Figure 1: Energy required to produce one tonne of aluminium, glass, bleached paper, unbleached paper, polyethylene, polyethylene terephthalate, polystyrene and polyvinylchloride, from raw materials and recycled materials

The energy required to produce one tonne of material from raw materials takes into account the energy expended in the extraction and mining of the principal raw materials, the refining and pre-treatment processes, and the manufacturing of usable products. The energy required to manufacture products from recycled materials takes into account the energy expended in collecting, sorting, pre-treating and reprocessing the recyclable materials. The energy expended in transporting the various materials, from one site to another, is also included.

4.1. Aluminium

The production of aluminium from raw materials is an energy intensive process. Based on the aluminium industry operating within Australia, the extraction of bauxite and transport to an alumina refinery in the Kwinana Industrial area, requires approximately 6 gigajoules of energy per tonne of aluminium that is finally produced.

The refining process and production of alumina requires between 40 and 60 gigajoules per tonne of aluminium, depending primarily upon the quality of the ore body, and the bauxite extracted. From Kwinana, the shipping of alumina interstate to a Melbourne based aluminium smelter requires a further 6 gigajoules per tonne of aluminium. During the production of aluminium ingots, a further 270 to 300 gigajoules per tonne is consumed. The further process of sheeting aluminium, manufacturing and use of an aluminium can requires 75 gigajoules per tonne of aluminium (AEC, 1979).

Therefore, it requires some 400 to 450 gigajoules of energy to produce one tonne of aluminium from raw materials, and to place it in circulation as a beverage can. Approximately 59000 aluminium cans are equivalent to one tonne of aluminium.

Alternatively, scrap and secondary sources of aluminium can be resmelted into aluminium ingot, sheeted and manufactured into cans. A fraction of 'new' aluminium is also placed in the batch. Aluminium cans are readily exploited as a secondary resource.

Initially, the aluminium must be collected and transported to a sorting plant and crushed, requiring 1.60 gigajoules per tonne of aluminium. Transport from the Perth metropolitan area to the Melbourne smelter consumes an estimated 3.45 gigajoules per tonne. The process of smelting secondary aluminium and forming ingot consumes less than 15 gigajoules of energy per tonne of aluminium. In all, producing one tonne of aluminium from recycled aluminium, and placing it in circulation, consumes only 5% of the energy required to produce one tonne from raw materials, a figure also quoted by the aluminium industry of Western Australia, and Australia.

Transporting aluminium interstate for recycling is approximately 20% of the total energy expended on recycling, and is less than the energy expended on the mining of bauxite.

Figure 2 is a relative comparison of the energy expended in producing aluminium from raw materials and secondary resources, the stages of energy expenditure being:

Production of aluminium from raw materials

1 Mining and extraction of bauxite and materials
2 Transport of bauxite to alumina refinery
3 Refining of bauxite and production of alumina
4 Transport of alumina to aluminium smelter
5 Production of aluminium ingot, sheeting, can production

Production of aluminium from recycled materials

1 Recycling material collection door to raw door
2 Transport to sorting site
3 Sorting and crushing of aluminium
4 Transport to remelter
5 Production of aluminium ingot
6 Energy saved by recycling aluminium cans

Aluminium production

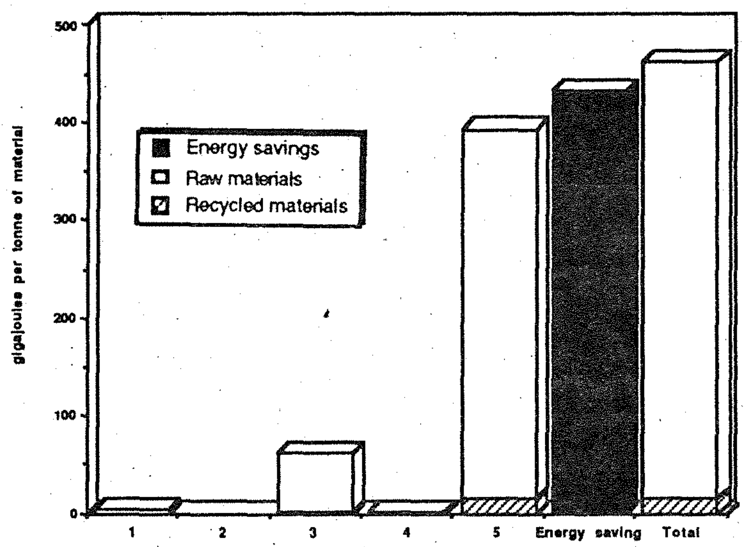

Figure 2: Energy required to produce one tonne of aluminium from raw materials and from recycled aluminium

The collection of aluminium cans throughout Western Australia for recycling has been carried out for several years now. During 1988 - 1989 financial year Comalco estimated that there was a 47% collection rate of cans that had been sold throughout the State in the same period. Throughout 1989, the collection rate increased to over 50%, with a total collection around 2800 tonnes. With an estimated 3000 tonnes of aluminium continuing to go into landfill annually, $3.75 million of potential revenue is being lost from the economy, and approximately 1.04 petajoules of energy wasted. This is equivalent to the annual energy requirements of 80000 Perth homes.

4.2. Glass

Glass is produced locally within the Perth metropolitan area, yet less than 30% of the annual production of glass in circulation each year is collected for recycling. The majority of glass discarded in urban refuse is from food and beverage packaging. Depending on the nature of the glass, it can be recycled in the following manner:

- crushed and remelted as cullet, that is, for broken and non-returnable or non-refillable glass containers and bottles;
- cleaned, sterilised and refilled, that is, returnable or refillable glass containers.

Assuming that the extraction and refining of all the necessary raw materials for glass manufacturing is carried out in Western Australia, then for every tonne of glass that is produced, around 15 gigajoules of energy is consumed. When glass is collected from the Perth metropolitan area and recycled, then a 40% energy saving is achieved for every subsequent tonne of glass that is produced.

Due to the nature by which raw materials form molten glass in the furnace, and the way in which cullet melts, the amount of energy saved is a function of the amount of cullet used in the furnace mix. During 1989, approximately 12200 tonnes of glass was collected for recycling in Western Australia, however, $2.20 million of glass or cullet was buried or unaccounted for, and assumed to have ended up in landfill sites. This wastage represents a loss of 300 terajoules of energy, equivalent to the annual requirements for 23000 Perth homes.

Figure 3 shows the percentage of energy consumption of each major stage in the production of glass from raw materials, recycling of glass, and reusing a glass containers. This is based on:

Glass from raw materials	**Glass recycled**	**Glass containers and bottles reused**
1 Extraction of sand and other raw materials	1 Recycling material collection door to door	1 Recycling material collection door to door
2 Transport to refinery	2 Transport to sorting site	2 Transport to sorting site
3 Refining of raw materials	3 Separation and sorting of glass, and the crushing of non-fillable bottles and broken glass	3 Separation and sorting of glass, and the washing and sterilising of refillable containers and bottles
4 Transport to glass manufacturer	4 Transport to glass manufacturer	4 Transport of refillable containers and bottles to industry
5 Manufacture of glass	5 Manufacture of glass	5 Industrial washing and sterilising if required
	6 Energy saved by recycling glass	6 Energy saved by reusing glass containers and bottles

Glass production and reuse

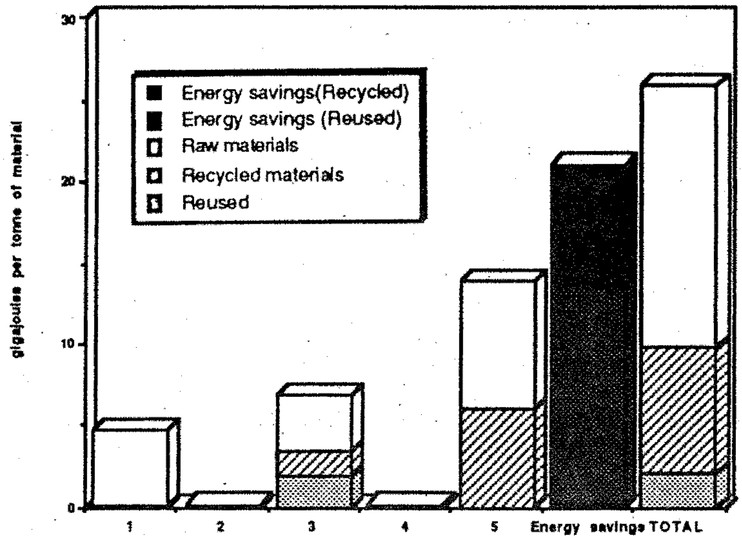

Figure 3: Energy required to produce one tonne of glass from raw materials, recycled glass and the energy required to reuse one tonne of glass containers

The use of a refillable bottle is around 80% more energy efficient than manufacturing molten glass from raw materials, and 70% more efficient than producing glass from cullet, that is, recycled glass.

4.3. Paper

Paper represents the bulk of the readily recyclable material, by weight, in domestic refuse, newsprint and cardboard accounting for 20% of this total, the remainder comprising mixed quality grade papers, such as high quality computer printing or photocopy paper, plastic coated papers such as milk cartons, and magazines. An estimated 200000 tonnes of paper based products are discarded and landfilled annually.

Approximately 90% of these paper products would have been produced from 100% virgin wood pulp. Less than 1% is produced from totally recycled paper pulp, the remaining 9% being a mix of wood pulp and recycled paper.

Two tonnes of chipped hardwood is required to produce one tonne of wood pulp that is converted into paper. To produce one tonne of unbleached paper, between 80 and 100 gigajoules of energy are required, depending on the type of wood pulp that is used, and the required final quality of the paper. An additional three to 13 gigajoules of energy are consumed in the bleaching of paper. Producing paper from recycled paper pulp, rather than wood pulp, achieves around a 70% energy saving for bleached and non-bleached paper products alike.

Around 25% of the newspaper, cardboard and quality paper consumed annually in Western Australia is recycled, despite the fact that the fibre from the same piece of paper can be recycled five to 20 times, depending on the original quality of the fibre. In general terms, between $10 million and $13 million of paper is buried annually in landfill, and whilst representing a waste of approximately 24 petajoules of energy, it also represents the loss of around 450000 tonnes of woodchips per annum. Essentially, this means that millions of trees are buried each year in landfill.

Locally, newspaper is being utilised as an insulation fibre, additive to grass seeding processes, and as a substitute for wood in the form of paper logs (produced by Good Samaritan Industries). An export market for old newsprint collected in Western Australia does exist, with the company currently operating at less than 25% capacity.

Figure 4 is an energy consumption analysis for the production of bleached paper from primary and secondary resources. The energy requirement is based on:

Bleached paper production from wood

1 Felling and chipping of trees
2 Transport to wood pulper
3 Grinding, pulping, bleaching
4 Transport to paper manufacturer
5 Bleached paper production

Bleached paper production from recycled paper pulp

1 Recycling material collection door to door
2 Transport to sorting site
3 Sorting, baling, grinding, pulping, bleaching
4 Transport to paper manufacturer
5 Bleached paper production
6 Energy saved by recycling paper

Bleached paper production

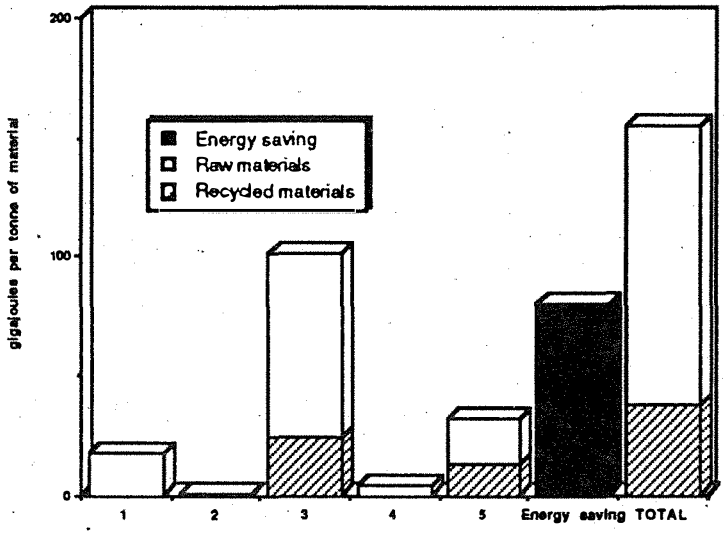

Figure 4: Energy required to produce one tonne of bleached paper from wood and from recycled paper

Figure 5 is an energy consumption analysis for the production of non-bleached paper from wood and recycled paper.

Unbleached paper production from wood

1 Felling and chipping of trees
2 Transport to pulper
3 Sorting, grinding, pulping
4 Transport to paper manufacturer
5 Unbleached paper production

Unbleached paper production from recycled paper pulp

1 Recycling material collection door to door
2 Transport to sorting site
3 Sorting, baling, grinding, pulping
4 Transport to paper manufacturer
5 Unbleached paper production
6 Energy saved by recycling paper

Unbleached paper production

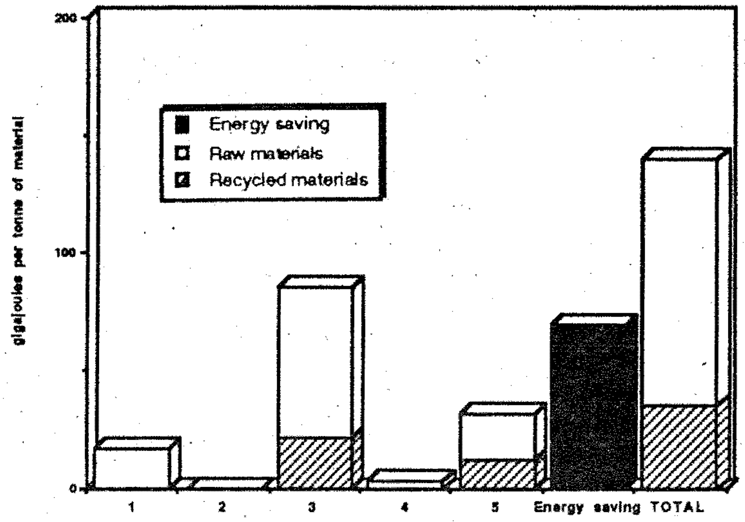

Figure 5: Energy required to produce one tonne of unbleached paper from wood and from recycled paper

4.4. Plastic

Per capita, consumption of plastics in Australia is estimated to be around 55kg per person annually, contributing around 8% to the weight of domestic refuse. With an estimated 30000 tonnes of plastic being discarded in Western Australia annually (60% of consumption is for long term use items), only a small percentage of production is being recycled, (PIA Inc, 1989), in fact less than 2000 tonnes Australia wide. The energy that goes into producing plastics varies greatly, depending on the processes involved and the type of plastic being produced. To allow for this variation, five types of thermoplastics have been analysed, their selection being based on those plastics found most frequently in domestic refuse.

Polyethylene is usually classified as either high density or low density. Items made from low density polyethylene (LDPE) include plastic shopping, storage, and 'boutique' bags, food wrapping and horticultural and gardening plastic. High density polyethylene (HDPE) has widespread use as food and beverage packaging, such as the one and two litre Masters, Brownes, Peters, and Harvey Fresh milk containers, all produced locally by Masters Dairy in Bentley. These containers are suitable for recycling, with the potential for the material to be used as the base resin from which new containers can be made. Over 1000 tonnes of HDPE milk containers will be produced and used in Western Australia this year. Over 800 tonnes found their way into Western Australian landfill sites last year.

Composition of domestic refuse by plastic type

• high density polyethylene (HDPE)	28%
• low density polyethylene (LDPE)	30%
• polyethylene terephthalate (PET)	8%
• polypropylene(PP)	16%
• polystyrene (PS)	6%
• polyvinyl chloride (PVC)	8%
• other	4%

Polyethylene terephthalate, or PET, is a light-weight and shatter-proof plastic used for soft drink containers. PET bottles contribute 0.3% by weight to domestic refuse (BRRU, 1989), equivalent to 20 million, two litre bottles, annually in Western Australia alone. The manufacturer of these PET containers puts the annual Australian import and conversion of PET resin at 20000 tonnes. The current PET reprocessing capacity of existing plants is 500 tonne. An additional 1000 tonnes is being stockpiled for use in the proposed Wodonga plant. Consequently 18 500 tonnes of PET soft drink containers, Australia wide, will find their way into landfill this year. During May this year 1.2 tonnes of PET containers were returned to ACI Plastics Packaging (Bentley, Western Australia) for reprocessing.

The producers of polyethylene products advocate the ease with which LDPE and HDPE, and PET can be recycled, but the number of places within Western Australia and, Australia, currently recycling these post consumer plastics is severely limited. Prototype PET recycling plants have been established by ACI Petalite in Blacktown, and a new plant is due to be built in Wodonga (Victoria) later this year, and by Smorgon Consolidated Industries in Melbourne. Polypropylene products, such as ice cream, cream cheese and yogurt containers, are being reprocessed and recycled into flower pots locally by Smith and Nephew Plastics (Bayswater).

Plastic manufacturers and recyclers have conveyed the importance of waste plastics being separated according to the type of resin they are made from (that is, HDPE, LDPE, PET, PP, PS, PVC, and the like), and cleaned of all debris, such as labels, tags, dirt and other contaminants, before they will recycle the plastic. Labels on plastic cause problems for people wanting to recycle because many are impossible to remove without the use of a strong solvent. The further separation of plastics according to resin type is again difficult for the simple reason that many plastic products are not easily identifiable as one resin or another, and parts of the container may also be of different resins.

To overcome these problems, it is necessary for plastic manufacturers to assist consumers and collectors by initiating a very obvious coding system for all plastics in use so that they can be separated accordingly. Secondly, where labels are placed on plastic, they should be readily removable or of the same plastic so they can be recycled in the same process as the plastic. The Plastics Packaging Division within the Plastics Institute of Australia Incorporated, have adopted a voluntary coding system for plastic containers based on the system being adopted in the United States of America (mandatory coding by 1991). The code is beginning to appear on the base of some containers and shopping bags available in Western Australia. An official launch of the coding system, by the PIA, will take place during 1990.

With around 30000 tonnes of plastic being landfilled annually in Western Australia, approximately 4 petajoules of energy are being wasted. This is sufficient energy to supply the annual requirement of 290000 Perth homes. The recent introduction of photodegradable and biodegradable plastics is ineffective in reducing the amount of plastics that are being landfilled, and does not lead to a reduction in the total energy expenditure of plastic production.

Members of the plastics industry have alluded to potential problems within future plastic recycling schemes where degradable plastics are present, claiming that they may reduce the strength and quality of the recycled product. This has been counteracted by the manufacturers of degradable plastics. Evidence in support of either allegation is yet to be forthcoming.

The major stages of energy expenditure in the manufacturing of plastics have been analysed as shown below, for high density polyethylene, low density polyethylene, polyethylene terephthalate, polypropylene, polystyrene and polyvinyl chloride.

Plastic from raw materials

1. Mining and extraction of raw materials
2. Transport of raw material to refinery
3. Conversion; polymerisation; resin manufacture; granulation
4. Transport of granules to plastic products manufacturer
5. Manufacture of plastic product

Recycling of plastic

1. Recycling material collection door to door
2. Transport to recycling centre
3. Sorting, washing, reprocessing, granulation, drying of plastic
4. Transport to plastic products manufacturer
5. Manufacture of plastic product
6. Energy saving by recycling plastic

High density polyethylene production

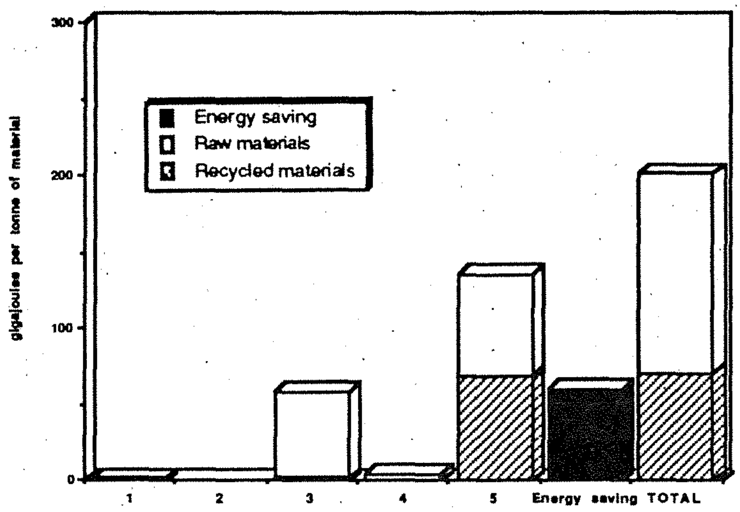

Figure 6: Energy required to produce one tonne of high density polyethylene from raw materials and from recycled high density polyethylene

Low density polyethylene production

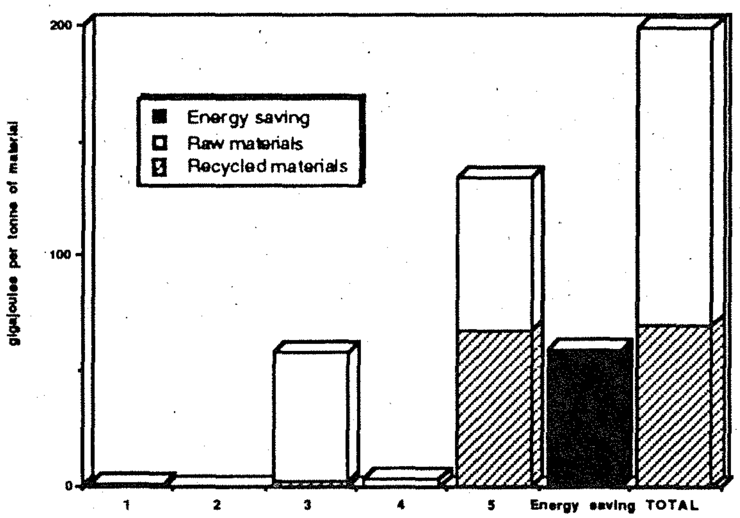

Figure 7: Energy required to produce one tonne of low density polyethylene from raw materials and from recycled low density polyethylene

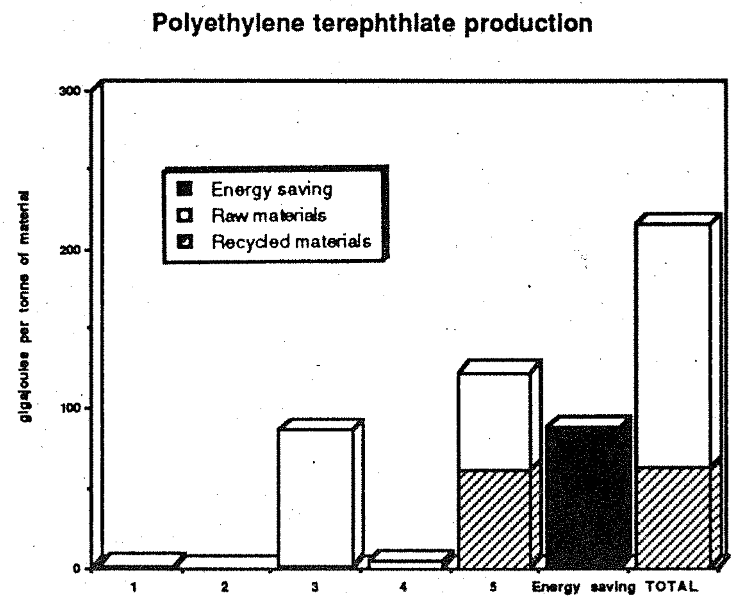

Figure 8: Energy required to produce one tonne of polyethylene terephthalate from raw materials and from recycled polyethylene terephthalate soft drink bottles

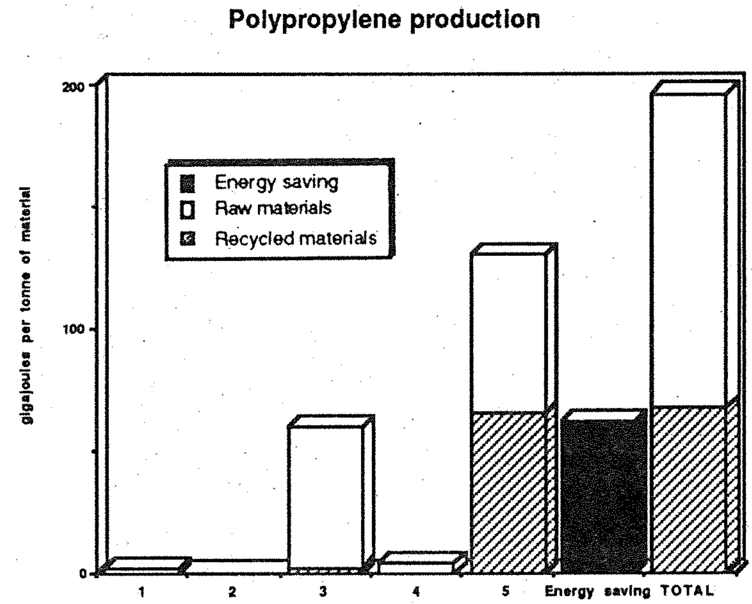

Figure 9: Energy required to produce one tonne of polypropylene from raw materials and from recycled polypropylene

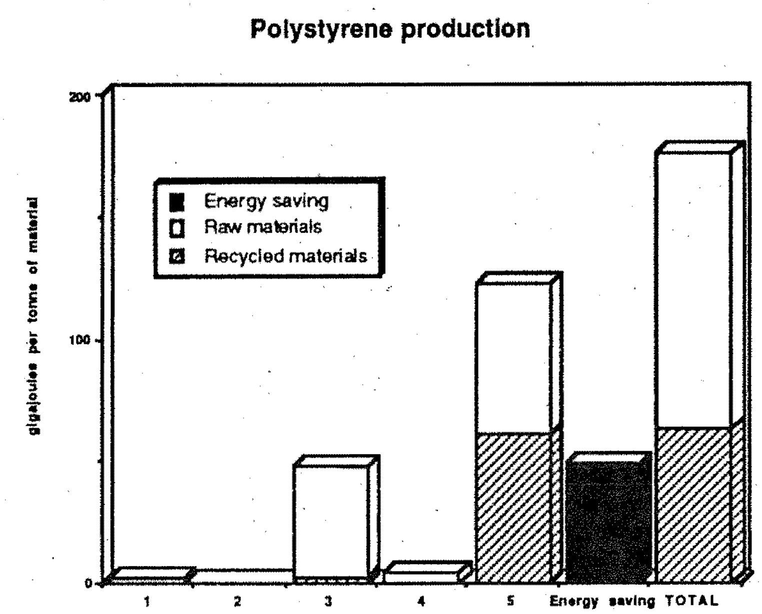

Figure 10: Energy required to produce one tonne of polystyrene from raw materials and from recycled polystyrene

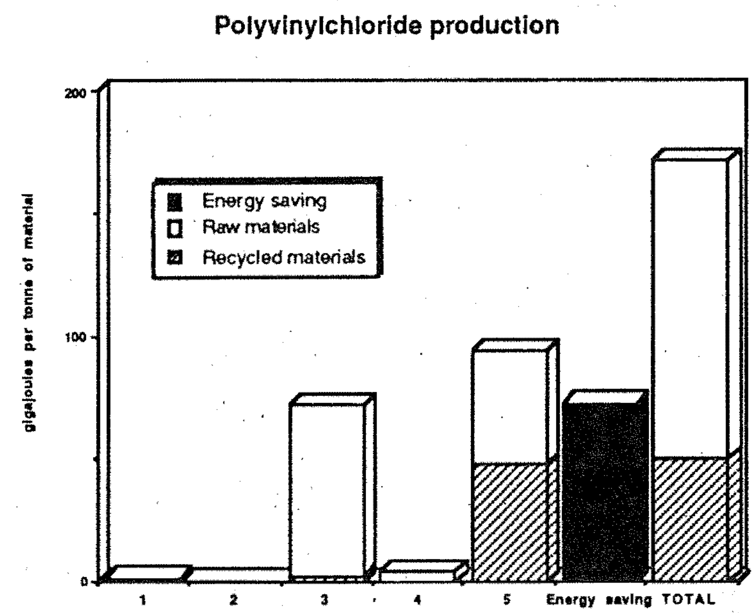

Figure 11: Energy required to produce one tonne of polyvinyl chloride from raw materials and from recycled polyvinylchloride

An energy saving in the range of 40% to 60% is achieved in the recycling of plastic, depending primarily on the type of plastic being recycled.

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Appendix 1

Average refuse composition in the Perth metropolitan area

The estimated composition of domestic refuse generated in the Perth metropolitan area is categorised below (as percentage by weight).

Composition	Percentage of total
Recyclable organics	20 - 40%
Recyclable inorganics and plastic	30 - 60%
Non-recyclables	5 - 10%
Recyclable organics	
food waste	25 - 35%
garden waste	20 - 25%
Recyclable inorganics and plastics	
aluminium	1 - 2%
glass	8 - 10%
*paper	20 - 30%
*plastic	5 - 10%
steel	1 - 3%

*paper

- packaging and cardboard (11 - 13%)
- newsprint (10 - 11%)
- stationery, magazines (3 - 4%)

*plastic

- polyethlene (1 - 5.5%)
- PET (0.1 - 0.5%)
- polypropylene (0.1 - 1.5%)
- polystyrene (0.5 - 2.5%)
- polyvinyl chloride (1 - 3%)

Appendix 2

Revenue generated from the sale of recyclable materials (per kilogram of waste generated per dwelling)

Material for recycling	Rate of payment for material	Revenue received per kilogram of refuse generated ($)
Aluminium	$700 per tonne $800 per tonne $1250 per tonne	0.0070 - 0.0140 0.0080 - 0.0400 0.0125 - 0.0250
Glass	$27 per tonne $45 per tonne $55 per tonne	0.0021 - 0.0027 0.0036 - 0.0045 0.0044 - 0.0055
Newspaper	$30 per tonne $35 per tonne	0.0030 - 0.0033 0.0035 - 0.0038
Cardboard	$40 per tonne	0.0040 - 0.0052
Polyethylene terephthalate	$700 per tonne	0.0030 - 0.0090
Steel	$150 per tonne	0.0060 - 0.0075
Polypropylene (ice-cream, cream cheese, yogurt containers)	($0.02 to $0.05 per container)	
Motor oil	($0.01 per litre)	
Polyethylene (sheet and film; milk containers)	($100 per tonne)	

Appendix 3

a) Realistic rate of return based on current market prices (June 1990)

b) Realistic rate of return based on fund-raising organisation prices (June 1990)

a Realistic rate of return based on current market prices.

Number of dwellings	500	1000	1500	2000	2500	3000	3500	4000	4500	5000
Participation	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
5kg	$65	$135	$200	$270	$335	$405	$470	$540	$605	$675
	$160	$325	$490	$650	$815	$980	$1145	$1310	$1470	$1635
10kg	$135	$270	$405	$540	$675	$810	$945	$1080	$1215	$1350
	$325	$650	$950	$1310	$1635	$1965	$2290	$2620	$2945	$3275
15kg	$200	$405	$605	$810	$1010	$1215	$1415	$1620	$1820	$2025
	$490	$980	$1470	$1965	$2455	$2945	$3435	$3930	$4420	$4910
20kg	$270	$540	$810	$1080	$1350	$1620	$1890	$2160	$2430	$2700
	$650	$1310	$1965	$2620	$3275	$3930	$4585	$5240	$5895	$6550
25kg	$335	$675	$1010	$1350	$1685	$2025	$2360	$2700	$3035	$3375
	$815	$1635	$2455	$3275	$4090	$4910	$5730	$6550	$7365	$8185
30kg	$405	$810	$1215	$1620	$2025	$2430	$2835	$3240	$3645	$4050
	$980	$1965	$2945	$3930	$4910	$5895	$6875	$7860	$8840	$9825
50kg	$675	$1350	$2025	$2700	$3375	$4050	$4725	$5400	$6075	$6750
	$1635	$3275	$4910	$6550	$8185	$9825	$11460	$13100	$14735	$16375
60kg	$810	$1620	$2430	$3240	$4050	$4860	$5670	$6480	$7290	$8900
	$1965	$3930	$5895	$7560	$9825	$11790	$13755	$15720	$17685	$19650

b Realistic rate of return based on fund raising organisation prices.

Number of dwellings	500	1000	1500	2000	2500	3000	3500	4000	4500	5000
Participation	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
5kg	$45	$90	$140	$185	$235	$280	$325	$375	$420	$470
	$75	$155	$235	$315	$390	$470	$550	$630	$705	$785
10kg	$90	$185	$280	$375	$470	$565	$655	$750	$845	$940
	$155	$315	$470	$630	$785	$945	$1100	$1260	$1415	$1575
15kg	$140	$280	$420	$560	$705	$845	$985	$1125	$1265	$1410
	$235	$470	$705	$945	$1180	$1415	$1650	$1890	$2125	$2360
20kg	$185	$375	$560	$750	$940	$1125	$1315	$1500	$1690	$1880
	$315	$630	$945	$1260	$1575	$1890	$2205	$2520	$2835	$3150
25kg	$235	$470	$705	$940	$1175	$1410	$1645	$1880	$2115	$2350
	$390	$785	$1180	$1575	$1965	$2360	$2755	$3150	$3545	$3935
30kg	$280	$560	$845	$1125	$1410	$1690	$1970	$2255	$2535	$2820
	$470	$945	$1415	$1890	$2360	$2835	$3305	$3780	$4250	$4725
50kg	$470	$940	$1410	$1880	$2350	$2820	$3290	$3760	$4230	$4700
	$785	$1575	$2360	$3150	$3935	$4725	$5510	$6300	$7085	$7875
60kg	$560	$1125	$1690	$2255	$2820	$3380	$3945	$4510	$5075	$5640
	$945	$1890	$2835	$3780	$4725	$5670	$6615	$7560	$8505	$9450

NB: The two prices corresponding to the participation rate represent the range of return on materials sold for recycling.

At a 30% participation of 5000 dwellings approximately 1500 dwellings are consistently taking part in the scheme.

Assuming the average rate of refuse generation is 10kg per dwelling per week, then the sale of the recyclables can generate a revenue between $280 and $470.

Appendix 4

Collection and storage containers for householders and collection companies

Collection and storage containers for householders and collection companies

Types of receptacles currently in use for the collection of recyclable materials, in Western Australian recycling schemes include the polywoven bags, treated cardboard cartons, and plastic crates. The choice of receptacle should reflect the needs of the community that will be utilising them, whilst remaining easy and efficient to collect by the scheme's operator. The durability of each type of receptacle is important to consider, especially in terms of the number of times that each receptacle can be used. The receptacle needs to be able to accommodate aluminium cans, glass, paper, plastic, steel cans, rags, cloth, and other material deemed by the council or collector to be recyclable through the scheme. The container should also be resistant to water in order to prevent water damage to paper.

Through the use of a bag type collection scheme, the collector need only make one trip per dwelling per collection by offering the exchange of filled bags for empty bags. The collected bags and their contents can be further sorted at the end of the collection when the vehicle returns to the yard. These bags can then be exchanged for more used bags during the next collection. It should be noted that twice the number of bags will be required for this exchange than if the bags contents are emptied onto the truck. Depending on the treatment the bag receives, the minimum lifetime expected is in the vicinity of six months.

Treated cardboard cartons and plastic crates are somewhat more expensive to purchase and replace than the polywoven bags. Treated cardboard cartons also have a shorter life span, around three months, and, along with the plastic crates, are likely to be put to other uses. Operating an exchange of cartons/crates on the day of collection would necessitate finding additional space on the truck for 1000 cartons or crates. If each carton or crate was to be emptied immediately and returned to the dwelling from which it was collected, then the runners are unnecessarily increasing their energy expenditure and the time required to complete the collection round by having to make two visits per house per collection. However, for aesthetic reasons, one council has chosen to continue with a plastic crate scheme, so as before, the selection of receptacles should take into account the needs of the community, ideally during the planning stage of the recycling scheme.

Multiple unit dwellings, such as high rise, may not be suited to individual recycling containers. The establishment of a communal collection area on site should be investigated to meet their needs.

It is envisaged that the recycling collection contractor will utilise storage containers of a greater capacity than those provided to each dwelling. It may be beneficial to the industries using recycled materials to enter into an agreement with the recycling collection contractor that addresses the provision of large storage containers at the depot, in return for clean sorted material suitable for recycling. This not only reduces the initial capital expenditure for the recycling contractor, but is an efficient way of reducing the handling costs of the materials.

Appendix 5

Energy equivalence values

Energy equivalence values

Fuel	Energy value
natural gas	38 MJ per cubic metre
propane	50 GJ per tonne
dry fire wood	16 GJ per tonne
motor spirit	46 GJ per tonne
coke	25 GJ per tonne
butane	49.5 GJ per tonne
industrial diesel oil	45.5 GJ per tonne
fuel oil	43 GJ per tonne
automotive distillate	45.7 GJ per tonne

1MJ (megajoule)	10^6 joules
1GJ (gigajoule)	10^9 joules
1TJ (terajoule)	10^{12} joules
1PJ (petajoule)	10^{15} joules
1kWh (kilowatt hour)	3.6 MJ

Appendix 6

a Summary of recycling activities initiated by Western Australian metropolitan municipalities

b Summary of recycling activities initiated by Western Australian country municipalities

a Summary of recycling activities initiated by Western Australian metropolitan municipalities

Municipality	Rates per residence for weekly rubbish collection (per year)	Charge for rubbish disposal at landfill site	Estimated tonnage disposed through weekly collection	Comments on the status of the landfill site	Status of recycling in the municipality
Armadale	$74			Chevin Road site recommended for closure to protect the environment	
Bassendean	$60	$10 per tonne	5280		
Bayswater		$10 per tonne	17582		Door-to-door service under consideration. Drop off depot at transfer station.
Belmont	$90	$10 per tonne	14581		Door-to-door service under consideration.
Canning	$66	$105 per 20m^3	22896	Ranford Road site undesirable due to groundwater pollution	
Claremont	$62.40				Under consideration. Tenders called for in 1990.
Cockburn	$60	$25 per tonne	15000	Henderson landfill developed as a regional site	Tenders for household collection service called during May 1990. Resident survey July 1990.
Cottesloe	$75				Fortnightly household collection service operating since 1988.
East Fremantle		$88 per 20m^3		Disposal site undesirable	Fortnightly household collection service operating since February 1990.
Fremantle	$70	$50 per tonne	13000		Fortnightly newspaper collection soon to be expanded to include additional recyclable materials during August.
Gosnells	$61.50	$105 per 20m^3	30000	Closure of site within next 10 years	Tenders called April 1990. No service provided.
Kalamunda	$69	$18 per tonne			Under consideration
Kwinana	$72				Recycling strategy developed. Tenders called July 1990.
Melville	$72	$88 per 20m^3			Limited drop off facilities available at landfill site - to be expanded during September 1990.
Mosman Park	$70				Tenders called July 1990.
Mundaring	$86		15000		

Nedlands		$3 per tonne		Weekly collection service commenced March 1990.
Peppermint Grove				Under consideration
Perth			37260	60% of residences provided with a weekly newspaper and glass collection service. Service to be expanded during 1990/91 to remainder of council area. Crates provided.
Rockingham	$73	$13 per tonne	31000	Under consideration.
Serpentine-Jarrahdale	$59			
South Perth	$95		20024	Tenders called June 1990.
Stirling	$95		34000	Some council collection vehicles will accept glass bottles - space on board limited. Drop off facilities available at transfer station.
Subiaco	$90			Weekly collection service commenced July 1990.
Swan	$75	$10 per tonne	14534	Pilot collection trial of 2000 homes in the Ballajura area.
Wanneroo	$100		40600	Future waste management strategy includes recycling. Fortnightly collection service to be operated by council. Tender called for recycling collection trucks July 1990.

b Summary of recycling activities initiated by Western Australian country municipalities

Municipality	Comments on the status of the landfill site	Status of recycling in the municipality
Town of Albany		Fortnightly recycling collection. First in the State. Commenced 1987.
Shire of Augusta-Margaret River		Recycling collection service proposed.
Shire of Bridgetown-Greenbushes		Recycling drop-off point located at Bridgetown tip site
City of Bunbury		Fortnightly recycling collection service commenced July 1990. Chemical container recovery programme.
Shire of Corrigin		Chemical container recovery programme.
Shire of Dardanup		Fortnightly recycling collection service commenced September 1990
Shire of Denmark		Tenders called 1990 for recycling collection service.
Shire of Donnybrook-Balingup		Recycling collection service proposed.
Shire of Dowerin		Chemical container recovery programme.
Shire of Esperance		Chemical container recovery programme.
City of Geraldton		Recycling collection service investigated and proposed by Council initiated Recycling Task Force.
Shire of Harvey		Weekly recycling collection service commenced 1989.
Shire of Katanning		Chemical container recovery programme.
Shire of Lake Grace		Chemical container recovery programme.
Town of Mandurah		Recycling collection service being considered.
Shire of Manjimup		Fortnightly recycling collection service commenced October 1990.
Shire of Merredin		Pilot project - centrally located aluminium, newspaper and plastic drop-off containers. Considering collection and separation facility at tip site. Chemical container recovery programme.
Shire of Mukinbudin		Considering recycling service and chemical container recovery programme.
Shire of Nannup		Private collector of recycling materials.
Shire of Narrogin		Chemical container recovery programme.
Town of Narrogin		Chemical container recovery programme.
Shire of Tammin		Chemical container recovery programme.
Shire of Tooday		Recycling drop-off point planned at proposed transfer station.
Shire of Trayning		Chemical container recovery programme.
Shire of Wongan-Ballidu		Chemical container recovery programme.
Shire of York		Recycling collection considered by council initiated Recycling Advisory Committee.