



Department of
Environment and Conservation (NSW)

Benefits of Recycling

May 2005



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1 Introduction

Over the last decade, kerbside recycling has consistently been cited as the behaviour that is most commonly performed in an attempt to mitigate the environmental impacts of our economy, with 95% of Australians recycling (ABS, 2003). Recycling has become a 'social norm', which taps into the community's legitimate and easily expressed desire to be involved in improving the environment – it makes participants 'feel good' and is considered a moral duty by some (ERV (2003) and BIEC (1997)).

In its NSW State of the Environment Report 2003, the Department of Environment and Conservation (NSW) estimated that over 300,000 tonnes of domestic kerbside recyclables were collected within the Sydney Metropolitan Area in 2001, equating to some 85 kilograms per capita per year and a recycling rate of close to 25%.

In order to maintain and enhance the attitudes and behaviours responsible for this high recycling rate, the Department of Environment and Conservation (NSW) has engaged Nolan-ITU to characterise a number of environmental benefits associated with recycling. This information may be used to enhance public awareness campaigns and educational programs, currently run by the Department of Environment and Conservation (NSW).

The most effective way to express this information is to make it captivating, vivid and concrete, i.e. make it stand out against all other information competing for audience attention. Vivid information is more likely to be remembered in the long term, having a sustained influence over attitudes and behaviour. Expressing the environmental benefits of a behaviour (such as kerbside recycling) to the target audience acts as a motivator to maintain and enhance such behaviour.

Therefore, the aim of this project is to develop tangible measures to express the environmental benefit associated with the recycling of materials. It should be noted that the derivation of typical kerbside recycling benefits has been based upon previous life cycle assessment (LCA) work in this area. However, this study should not be interpreted as an actual LCA. It is intended as the basis for presenting information to a wide public audience who may not be familiar with the concept/intricacies associated with this field of study.

2 Methodology

2.1 Data Sources and Assumptions

For the purposes of deriving easily communicable benefits associated with kerbside recycling, life cycle inventory (LCI) databases were used to determine the greenhouse benefits, energy savings and water savings associated with recycling a typical kerbside mix of the following materials:

- Paper/Cardboard;
- Liquidpaperboard (LPB);
- Glass;
- Aluminium;
- Steel;
- High Density Polyethylene (HDPE); and
- Polyethylene Terephthalate (PET).

Data has been drawn predominantly from the Stage 1 and Stage 2 Reports for *Life Cycle Assessment for Paper and Packaging Waste Management Scenarios in Victoria* undertaken for and published by EcoRecycle Victoria (Grant, T et al, 2001). In addition, the following sources have been used:

- *Solid Waste Management and Greenhouse Gases – A Life-Cycle Assessment of Emissions and Sinks*, (USEPA 2002);
- *Life Cycle Inventories for Packagings*, (BUWAL 1998);
- *Integrated Solid Waste Management – A Life Cycle Inventory*, (White et al 1997); and
- Nolan-ITU's in-house databases for waste and recycling.

The analysis covers only the direct benefits of recycling (compared with production/manufacture from virgin materials). All sorting and reprocessing losses have been taken into account however, it is important to note that the figures do not take into account avoided landfill impacts.

For the purposes of this study, the same kerbside recycling mix as that established to assess a range of domestic waste and recycling systems for the NSW Jurisdictional Recycling Group (2003) was used. Based upon this assumption, a figure of 4.56 kilograms per household per week (i.e. 237 kilograms per household per year) was taken to represent the total average capture quantity of recyclable materials. This figure corresponds with the capture rate reported within the National Environment Protection Council's 2001-2002 Annual Report (i.e. 228 kilograms per household per year). Table 2.1 details the mix of recyclables assumed for this analysis.

**Table 2.1: Assumed Kerbside Recycling Mix**

Material	Capture Quantity (kilogram per household per week)	%
Old Newsprint	1.03	22.6%
Liquidpaperboard (gabled)	0.01	0.2%
Liquidpaperboard (aseptic)	0.01	0.2%
Paper and Cardboard	0.42	9.2%
Glass	1.14	25.1%
Aluminium	0.03	0.7%
Steel	0.16	3.5%
HDPE	0.10	2.2%
PET	0.11	2.4%
Mixed Paper	0.75	16.5%
Contamination	0.79	17.4%
TOTAL	4.56	100.0%

Source: NSW Jurisdictional Recycling Group and Publishers National Environment Bureau (2003)

2.1.1 System Characterisation

a) System Boundary

Using the methodology of life cycle assessment (LCA), the environmental characteristics of material systems can be assessed from “cradle to grave”, including all impacts from raw materials extraction through to final disposal. Within this study, the benefits/impacts of recycled material systems have been deducted from virgin material systems to characterise the environmental benefits associated with recycling. For the recycling system, impacts arising from the material losses (i.e. net yields) have been considered, in addition to the impacts typically associated with collection, sorting and reprocessing activities.

b) Materials Collection and Transport

For the purposes of this study, the collection of recyclables is modelled as taking place within the Sydney metropolitan area. The collected material is then assumed to be delivered to a local materials reprocessing facility (MRF) within 20 kilometres of the collection area. After sorting, materials are sent to local and overseas reprocessors according industry feedback. For the purposes of this study, the following materials reprocessing destinations have been assumed:

- Paper/Cardboard – Local Australian reprocessors and Asian markets;
- Liquidpaperboard (LPB) – Shoalhaven;
- Glass – Botany (beneficiation) and Penrith (reprocessing);
- Aluminium – Yennora;
- Steel – Port Kembla;
- High Density Polyethylene (HDPE) – Penrith; and
- Polyethylene Terephthalate (PET) – Prestons.

2.2 Assessment Framework

Virgin product systems have been directly compared to recycled product systems to determine the environmental benefits associated with recycling each material type. In order to communicate the benefits associated with kerbside recycling, the indicators of greenhouse gases, energy and water savings have been chosen. It is considered that these indicators can be readily communicated to the general public, with all three indicators having had extensive media exposure over recent times.

2.2.1 Greenhouse Benefit Indicators

In characterising the greenhouse benefits, savings in the following gases/aspects are quantified:

- Carbon Dioxide;
- Methane;
- Nitrous Oxide; and
- Sequestration.

The savings have also been tallied in terms of overall carbon dioxide equivalence ($\text{CO}_{2\text{eq}}$) and tabled for ease of comparison between materials. It should be noted that methane (CH_4) has a global warming potential of 21 times that of carbon dioxide while nitrous oxide (N_2O) has a global warming potential of 310 times that of carbon dioxide.

2.2.2 Energy Savings Indicators

Energy savings resulting from recycling are presented for each material. In characterising the energy savings, offsets in the following categories are quantified:

- Delivered Electricity;
- Process Heat;
- Transport; and
- Miscellaneous Energy Inputs.

The energy savings are then compared to production from virgin materials, tallied in terms of overall savings for each material and tabled for ease of comparison.

2.2.3 Water Savings

As with energy savings, the water savings resulting from recycling are presented for each material. The savings for each material are then tabled for ease of comparison. Due to the quality of information available for Australia, water savings have been presented as an overall aggregated quantity rather than in its discrete forms such as process water, steam, etc.

2.2.4 Comparison with Other Data Sources

In order to provide a checking mechanism for local data used as the basis of this study, comparisons have been made against overseas life cycle data. This data is recognised as being of a high quality amongst LCA practitioners. It should be noted, however, that the overseas data occasionally refers to differing processes and specific local circumstances that may not be relevant to Australian conditions.



3 Environmental Benefits of Recycling

3.1 Greenhouse Benefits

Recycling results in the avoidance of environmental impacts associated with resource extraction and materials production/manufacturing processes. One impact area is global warming caused by the accumulation of greenhouse gases in the earth's atmosphere.

Table 3.1 details the quantity of greenhouse gases, expressed as kilograms of carbon dioxide equivalents, avoided by typical households participating in kerbside recycling schemes. Greenhouse gas avoidance is denoted in Table 3.1 by a positive number while greenhouse gas generation is denoted by a negative number.

A typical NSW household recycling 3.76 kilograms (net) avoids generating 106 kilograms of CO₂_{eq} each year as detailed in Table 3.1 and Figure 3.1. The greenhouse gas emissions avoided through recycling amount to 50% of the annual electricity consumption of a household for lighting, or almost 40% of the annual electricity consumption for cooking¹.

On a state-wide scale, 229,000 tonnes of CO₂_{eq} are avoided each year. This is equivalent to taking 55,000 cars off the road permanently².

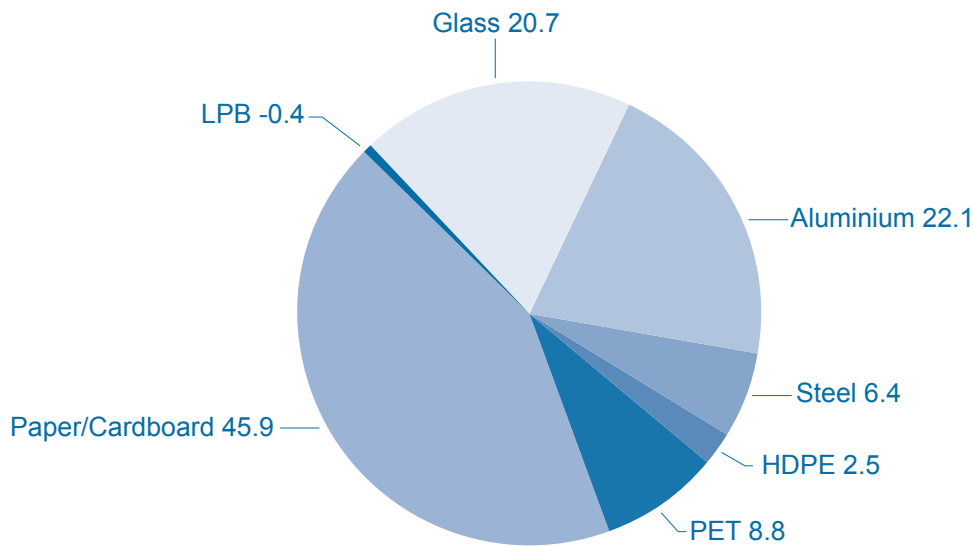
Table 3.1: Greenhouse Benefits of Recycling per Household (kilogram CO₂_{eq} per year)

Greenhouse Benefit Category	Paper/ Cardboard ¹⁾	Liquid Paper Board	Glass	Aluminium	Steel	HDPE	PET
Carbon Dioxide	28.7	0.0	20.3	20.1	5.6	2.1	8.3
Methane	3.9	-0.6	0.4	0.5	0.8	0.4	0.5
Nitrous Oxide	2.4	0.0	0.0	0.0	0.0	0.0	0.0
Sequestration	10.9	0.2	0.0	0.0	0.0	0.0	0.0
Other	0.0	0.0	0.0	1.5	0.0	0.0	0.0
Total (kilograms CO₂_{eq} per household per year)	45.9	-0.4	20.7	22.1	6.4	2.5	8.8
Total (mix) kilograms CO₂_{eq} per household per year	106						

¹⁾ Mixed paper and cardboard in kerbside recycling mix

¹ Australian Greenhouse Office (1998): *Strategic Study of Household and Energy Issues*, Chapter 5. Figures used for "efficient electric household".

² Australian Greenhouse Office, *Fuel Consumption Label – Fuel Consumption and the Environment*. (based upon an average mileage of 15,000 km/year)

Figure 3.1: Greenhouse Benefits of Recycling per Household (kilogram CO₂ eq)


Because the household recycling mix is dominated by paper and cardboard, the majority of the greenhouse benefits arise from the substitution of brown kraftliner and the avoided thermo mechanical pulping of wood. A significant benefit is also associated with the recycling of glass, which makes up almost one third of the recycling mix by weight. The greenhouse benefit associated with glass recycling arises mainly from the avoided processing of soda ash and lime, required to produce virgin glass batch.

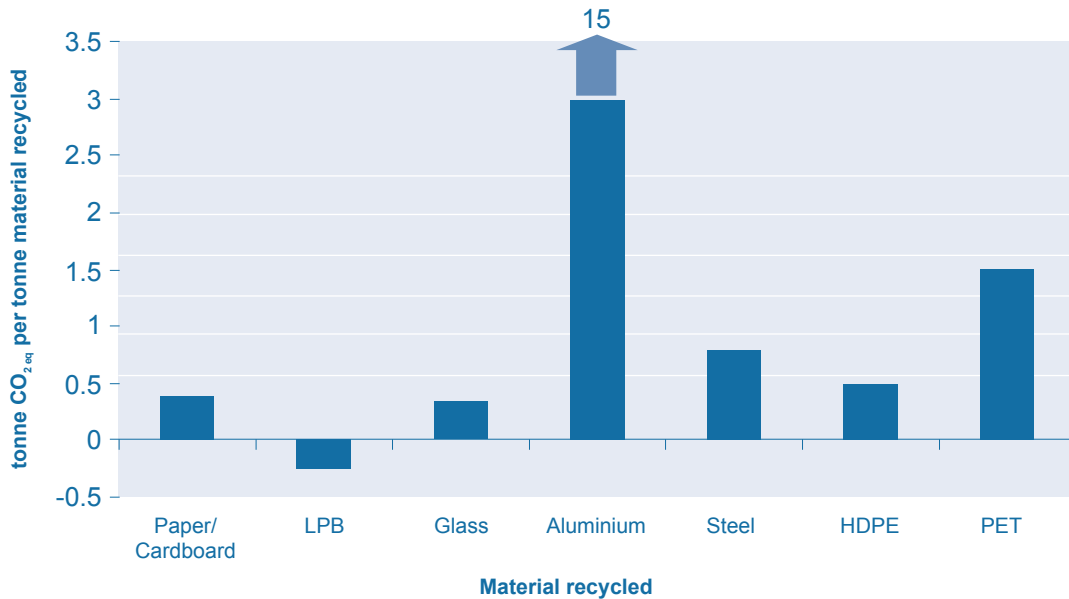
On a weight for weight basis, the recycling of aluminium results in significant greenhouse gas avoidance as shown in Table 3.2 and Figure 3.2. This is due to the high energy requirement of refining alumina to produce primary aluminium ingots. As a result, the recycling of only a small amount of aluminium is able to yield significant greenhouse benefits.

Table 3.2: Greenhouse Benefits of Recycling per Tonne (tonne CO₂ eq per tonne material recycled)

Greenhouse Benefit Category	Paper/ Cardboard	LPB	Glass	Aluminium	Steel	HDPE	PET
Carbon Dioxide	0.25	-0.02	0.34	13.80	0.69	0.42	1.42
Methane	0.03	-0.39	0.01	0.37	0.10	0.08	0.09
Nitrous Oxide	0.02	0.01	0.00	0.00	0.00	0.00	0.01
Sequestration	0.10	0.15	0.00	0.00	0.00	0.00	0.00
Other	0.00	0.00	0.00	1.00	0.00	0.00	0.00
Total (tonne CO₂ eq per tonne material)	0.40	-0.25	0.35	15.17	0.79	0.50	1.52



Figure 3.2: Greenhouse Avoidance from Recycling per Tonne (tonne CO₂eq per tonne material recycled)



A comparison of localised data with overseas data is given in Table 3.3. In comparing Australian results to international data, it may be seen that whilst the magnitude of savings differ slightly, the relative benefits of recycling each material are comparable. It should be noted that the difference between the Australian and USEPA data for paper/cardboard is due to different energy cogeneration practices at mills.

Table 3.3: Comparison of Australian Life Cycle Inventory (LCI) Data vs. International Data (tonne CO₂eq per tonne material)

	Paper/ Cardboard	Liquid Paper Board	Glass	Aluminium	Steel	HDPE	PET
Australian LCI Data	0.4	-0.2	0.3	15.2	0.8	0.5	1.5
USEPA	2.7	N/D	0.3	12.9	1.9	1.2	2.1

N/D – No Data

3.2 Energy Savings

In recent years, the association between energy consumption and the environment has become increasingly strong through the promotion of various energy efficiency programs, the increased uptake of renewable or ‘green electricity’ and greater awareness of greenhouse issues. Whilst it is public knowledge that recycling results in environmental benefits, the degree to which recycling results in energy savings is not well understood. One of the main reasons for this is the comparatively high visibility of downstream collection and sorting processes (energy inputs) as compared to the low visibility of upstream manufacturing and distribution (energy savings).

However, as shown in Table 3.4 and Figure 3.3, a typical household participating in a kerbside recycling scheme creates significant energy savings when compared to a virgin product system. Much of these energy savings arise from paper/cardboard recovery, where the energy required for harvesting raw materials,

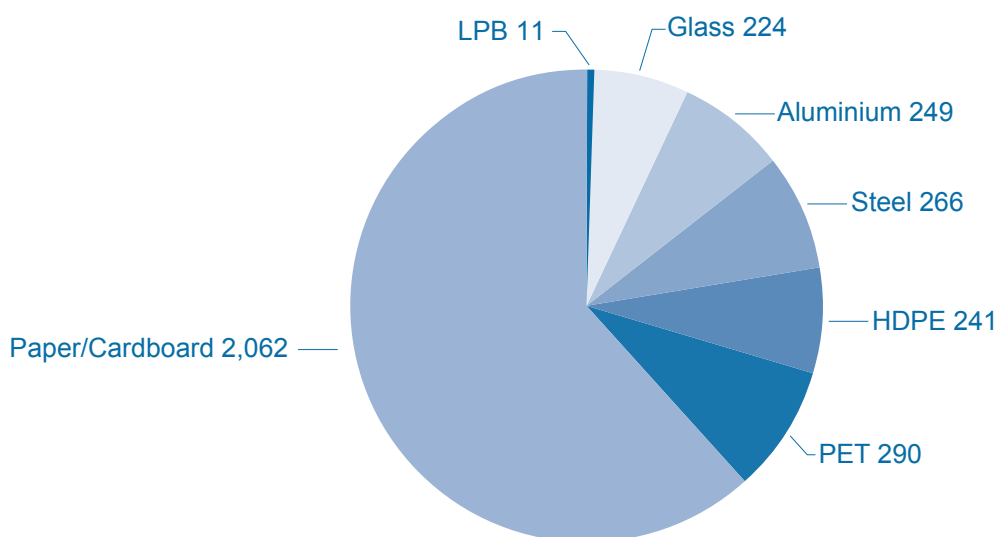
subsequent pulping activities and process heat are avoided. It should be noted here that much of the energy required for paper/cardboard production is generated through the combustion of biomass and, because greenhouse gas emissions from the combustion of biomass are considered to be part of the natural carbon cycle, energy savings associated with the recycling of paper and cardboard are considerably higher than the corresponding greenhouse savings.

As with greenhouse gases, energy savings are denoted as positive numbers whilst energy consumption is denoted by negative numbers.

Table 3.4: Energy Savings from Recycling per Household (megajoules per household per year)

Energy Savings Category	Paper/ Cardboard	LPB	Glass	Aluminium	Steel	HDPE	PET
Primary Energy (Electricity)	353	2	5	213	21	4	6
Process Heat	1,796	12	186	28	55	35	33
Transport	-87	-4	-10	0	-1	-20	-3
Other Energy Inputs	0	1	43	8	191	222	254
Total (megajoules per household per year)	2,062	11	224	249	266	241	290
Total for mix (kilowatt hour per household per year)	928						

Figure 3.3: Energy Savings from Recycling per Household (megajoules per year)



Whilst the greatest energy savings on a household basis arise from paper and cardboard, on a weight for weight basis the recycling of aluminium gives rise to the greatest energy savings (refer Table 3.5 and Figure 3.4). This is due to the energy intensive electrolytic process used to refine alumina to primary aluminium. Similarly, energy savings from steel are relatively high due the blast furnace heating requirement.

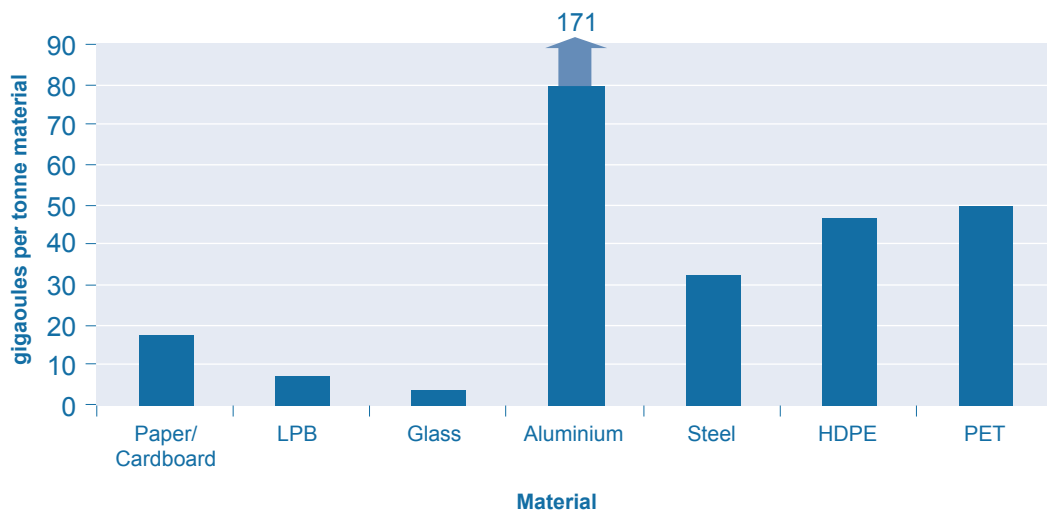


Table 3.5: Energy Savings from Recycling per Tonne (gigajoules per tonne)

Energy Savings Category	Paper/ Cardboard	Liquid Paper Board	Glass	Aluminium	Steel	HDPE	PET
Delivered Electricity	3.1	1.3	0.1	146.2	2.5	0.8	1.1
Process Heat	15.7	7.9	3.1	19.2	6.9	6.7	5.6
Transport ¹⁾	-0.8	-2.4	-0.2	0.0	-0.2	-3.8	-0.4
Other Energy Inputs	0.0	0.4	0.7	5.6	23.7	43.1	43.3
Total (gigajoules per tonne material)	18.0	7.2	3.7	171.0	32.9	46.8	49.6

¹⁾ Includes collection and transportation of recyclables from kerbside to MRF and from MRF to reprocessors (Sydney metropolitan area)

Figure 3.4: Energy Savings from Recycling per Tonne (gigajoules per tonne material)



The energy savings from recycling HDPE and PET are also high due to the energy products (oil and gas) which are used as feedstock to manufacture plastic. While there is significant energy embodied in polymers, it is generally unavailable for energy production. Therefore, as with paper/cardboard, energy savings associated with the recycling of HDPE and PET are considerably higher than the corresponding greenhouse savings due to the fact that the carbon within plastic is not oxidised to form greenhouse gases.

Based upon the available data, a household recycling the mix of materials assumed within this report would save approximately 928 kilowatt hours of electricity per year. This is equivalent to 15% of a household's annual electricity requirements³. Note that households with high recycling rates can 'save' up to a third of their total electricity consumption.

On a state-wide scale, some 2,005 gigawatt hours of electricity are currently being saved each year through kerbside recycling. This is equivalent to the annual electricity requirement of almost 334,000 households, or over 900,000 individuals.

A comparison of localised data with overseas data is given in Table 3.6. As may be seen, the results are generally comparable.

³ Based upon an average annual electricity consumption of 6,000kWh reported by Australian Greenhouse Office, *Strategic Study of Household Energy and Greenhouse Issues*

Table 3.6: Comparison of Australian Life Cycle Inventory (LCI) Data vs. International Data (gigajoules per tonne material)

	Paper/ Cardboard	Liquid Paper Board	Glass	Aluminium	Steel	HDPE	PET
Australian LCI Data	18.0	7.2	3.8	171.0	32.9	46.8	49.5
Overseas LCI Data	29.0 ^a	N/D	3.8 ^a	174.6 ^b	15.5 ^b	80.4 ^b	81.1 ^b

N/D – No Data a – Buwal (1998) b – White et al (1997)

3.3 Water Savings

With the low levels of rainfall across Australia in recent years, the issue of water and its conservation is gaining prominence. This is reinforced by the recent tightening of the current water restrictions which are likely to remain in force for the foreseeable future. Coupled with the increasing focus given to ‘water rights’ in the primary industry sector, river water quality and record low dam levels, water is increasingly being seen as a key environmental issue.

Unlike energy and greenhouse results which are linked to process thermodynamics and are therefore relatively constant between different plants, companies and countries, water usage can vary dramatically from plant to plant depending upon the technology being used and the availability of water. As a result, water usage can range from zero water processes to very high usage, particularly in countries with few limitations on water supply or those able to utilise saline waters for cooling, being situated near coastal areas.

Table 3.7 show that a household participating in a kerbside recycling scheme can make a significant contribution to water savings. This is largely due to the relatively high recovery of paper and cardboard, which is generally recognised as a water intensive process due to the wood pulping process for producing virgin fibres. Another lesser known water intensive process is the production of aluminium. This is due to the refining of bauxite which is converted to alumina using a wet chemical process. As a result, high water savings (on a weight for weight basis) are also achieved when aluminium is recycled. Within Table 3.7, the tonnes of water saved per tonne of material recycled are given. Here it should be noted that water savings are denoted as positive numbers whilst water consumption is denoted by negative numbers.

The recycling of HDPE and PET, whilst resulting in greenhouse and energy benefits, actually utilises more water than the virgin product system. This is due to the low density/high surface area nature of plastic containers and the sorting/washing process required during the reprocessing of these materials.

Based upon the available data, a household recycling the mix of materials assumed within this report would save almost 3,073 litres of water per year. This is equivalent to around 12 days of water consumption for one person⁴ (or flushing a toilet 615 times).

On a state-wide scale, some 6,634 megalitres of water are currently being saved each year. This is enough to fill 2,654 olympic sized swimming pools which is the equivalent of between three and five days of Sydney’s total water consumption.

⁴ City of Sydney, *State of the Environment Report 2002-2003* (http://www.cityofsydney.nsw.gov.au/environment/water/water_supply.html)

**Table 3.7: Water Savings from Recycling**

Water Savings Category	Paper/ Cardboard	Liquid Paper Board	Glass	Aluminium	Steel	HDPE	PET
Kilograms per household per year	2,714.0	14.0	120.0	340.0	9.0	-53.0	-71.0
Total for mix (kilograms per household per year)	3,073						
Tonne water per tonne material*	23.7	9.6	2.0	233.2	1.1	-10.4	-12.1

*One tonne of water is equivalent to 1,000 litres

A comparison of local data with overseas data as presented in Table 3.8 shows a number of differences in water savings/consumption. The main reason for these differences lies in the characteristics of the Australian reprocessing systems which are generally more water efficient than those of other countries.

Table 3.8: Comparison of Australian Life Cycle Inventory (LCI) Data vs. International Data – (tonne water per tonne material)

	Paper/ Cardboard	Liquid Paper Board	Glass	Aluminium	Steel	HDPE	PET
Australian LCI Data	23.7	9.6	2.0	94.5	1.1	-10.4	-12.1
Overseas LCI Data	N/A	N/D	-1.0 ^a	229.5 ^a	15.7 ^a	N/D	N/D

N/A – European and North American data differ to Australian data for paper recycling due to different paper reprocessing technologies. Australian data shows more efficient water use than recycling processes overseas.

N/D – No Data

a – ETH-ESU – Swiss Federal Institute of Technology, ESU – Services (Environmental Consultancy)

4 Conclusions

The environmental benefits associated with recycling have been quantified on a material basis; and for the typical domestic kerbside collection system, based on current average yields and the typical mix of materials collected in NSW. Three environmental indicators were used:

- Greenhouse Gas Savings;
- Energy Savings, and
- Water Savings.

Greenhouse Gas Savings

Based on available Australian greenhouse data, a typical household recycling 3.76 kilograms per week (net) avoids 106 kilograms of CO₂ eq each year. On a household basis this is equivalent to avoiding the greenhouse gas emissions from:

- 50% of the electricity used for lighting, or 40% of the electricity used for cooking.

On a state-wide basis about 229,000 tonnes per year of CO₂ eq is saved, equivalent to

- Taking 55,000 cars off the road permanently.

Energy Savings

Through participating in kerbside recycling, a typical household saves 928 kilowatt hours of electricity per year. This is equivalent to:

- 15% of a typical household's total electricity consumption, or
- 8 weeks per year of electricity consumption for each household.

On a state-wide basis an estimated 2,005 gigawatt hours of energy is saved. This is equivalent to:

- The total annual electricity consumption of around 334,000 households or almost 1 million individuals.

Water Savings

A typical recycling household avoids the consumption of 3,073 litres of water per year. This is equivalent to:

- The average water consumption of one person for 12 days.

On a state-wide scale some 6,634 megalitres of water is saved each year. This is equivalent to:

- 2,654 olympic swimming pools, or
- Between three days and almost one week of water supply for Sydney.

Outlook

All the above figures are based on the current average household yield of 3.76 kilograms per week of recyclable materials (net of contamination). As the better performing households are capable of recycling double this average yield, there is significant potential to further increase the quantities of recyclable materials collected, and hence further increase the environmental benefits achieved.

Commercial Recycling

To promote commercial recycling activities, the environmental benefits have been presented on a per tonne basis for each material. These can easily be extrapolated for a certain activity or a certain industry sector when combined with expected quantities and types of material recycled.

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