DISCUSSION PAPER

CARBON VALUE PROPOSITION OF CONTAINER DEPOSIT RECYCLING

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FOR

ECOS CORPORATION

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EXECUTIVE SUMMARY

The issue of climate change is arguably the major environmental challenge of the 21st century. However, while there may be some awareness that recycling reduces energy consumption, the direct link between recycling and carbon abatement has yet to be fully explored. This study into the carbon value proposition of container deposit recycling is a preliminary attempt at quantifying the greenhouse gas reductions achieved through increased recycling of packaging materials of manufacture.

Packaging, and in particular, container packaging is a pervasive part of every day modern life. Materials of container packaging manufacture include glass, steel, aluminium, polyethylene terephthalate (PET), high density polyethylene (HDPE) and other plastic (including plastic film lined liquid paper board). Australia consumed approximately 16 billion containers in 2005, with only an estimated 37 per cent, or 501,400 tonnes being recycled. The remaining 850,600 tonnes represents approximately 9.5 billion containers, or nearly 500 containers landfilled per person per year in Australia.

One of the major environmental impacts is associated with the energy requirements to manufacture the materials used in producing packaging, or the embodied energy. Embodied energy is the amount of energy used to transform raw materials into a final product or material. The amount of embodied energy in packaging materials is directly related to the carbon footprint of packaging, with nearly 0.1 tonnes of carbon dioxide equivalent (CO_2e) released for every giga-joule (GJ) of energy used.

For example the manufacture of one tonne of aluminium requires 206 GJ of energy to transform bauxite into alumina, and then alumina into aluminium smelting. The associated greenhouse gas emission from one tonne of aluminium manufacture is 20.2 tonnes of CO_2e. By contrast the energy used to recycle one tonne of aluminium for reuse is 14.1 giga-joules, a net saving in embodied energy of 191.9 giga-joules, which equates to a greenhouse gas saving (carbon abatement) of 18.8 tCO_2e.

The following analysis relates to the introduction across Australia of a system of 'container deposits' similar to that of South Australia's 5¢ refund on bottles and cans and the greenhouse savings that would result from such a policy. For the purposes of this analysis it has been assumed that a 10¢ deposit would result in a 90 per cent collection rate of glass, steel, aluminium, PET and HDPE containers, which is an additional 703,900 tonnes of recycling. (This is based on the fact the current 5¢ system in SA results in recycling rates of around 85%.) The embodied energy savings from recycling were estimated to be 18,828,000 GJ, which translates to a greenhouse gas reduction of 1,844,000 tonnes of CO_2e.

An estimated 110,000 tonnes of CO_2e was then netted out from this total abatement to account for potential increases in private travel (a maximum of 178 million kilometres) and also additional transport of recyclate from the point of collection to a processing facility and/or end-user (35 million kilometres or 1,000 kilometres for every 20 tonnes of recyclate). However, the negation of some of the greenhouse savings due to a possible increase in personal transport is likely to be an overestimate as very few additional trips to return containers would be made outside of existing shopping, work, school drop-off or leisure excursions.

This increase in recycling attributable to the implementation of a 10¢ deposit on containers in Australia presents a carbon abatement potential of 1,734,000 tonnes of CO_2e. This level of carbon abatement is nearly 12 per cent of the national greenhouse gas emissions from solid waste and is equivalent to avoiding the burning of 655,000 tonnes of black coal, which is the same reduction in greenhouse pollution as taking approximately 350,000 cars off the road.

This preliminary investigation has identified that whatever the ultimate outcome in terms of greenhouse gas savings from increased recycling would be in Australia with the introduction of CD, the savings are significant and any possible increased transportation has a negligible effect. It is recommended that the carbon abatement value of container deposits be included as part of any benefit and cost analysis of CD schemes.

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1 INTRODUCTION

The issue of climate change is gaining rapid traction with policy decision makers and community members alike as the major environmental challenge of the 21st century. However, while there may be some awareness that recycling reduces energy consumption, the direct link between recycled materials using less energy and carbon abatement has yet to be fully explored. In fact, until recently the overall environmental benefit of recycling has been open to question. A recent UK WRAP study confirmed that 'recycling offers more environmental benefits and lower environmental impacts than other waste management options.'[1]

Warnken ISE was commissioned by Ecos Corporation to examine the carbon value proposition of increased recycling brought about through the use of Container Deposits. In particular, the link between recycling of packaging materials and a reduction in greenhouse gas emissions through savings in embodied energy. Warnken ISE was not, for the sake of this report, asked to quantify other environmental and social benefits of a CD systems, such as water savings, reduced litter, reduced costs to local government or social nuisance of lacerations from broken bottles, etc.

1.1 Methodology and Approach

The approach taken for this study was to examine the potential carbon benefits as defined by energy savings achieved through the direct recycling of materials likely to be covered by a container deposit. These materials include glass, steel, aluminium, polyethylene terephthalate (PET) and high density polyethylene (HDPE).

The starting point was to convert likely performance levels of recycling arising from a 10¢ deposit on containers into tonnes of materials. These volumes were then used to calculate the likely energy savings arising from differences in embodied energy between virgin material and recycled material. The energy savings were then converted into tonnes of carbon dioxide equivalent (CO_2e) using a scaling factor developed by CSIRO for Australian conditions. An estimate was also made of the likely carbon impact from any additional transport associated with the CD scheme and was 'netted out' from the total carbon abatement benefit that could be realised from a national implementation of Container Deposits.

This approach thus delivers an estimate of the potential greenhouse benefits from energy savings achieved through direct recycling of packaging materials, with some allowance made for transport greenhouse emissions. It is not a Life Cycle Assessment (LCA) of current practice in recycling. LCA could yield different 'per tonne' abatement potential where:

– non-energy emissions are included in the analysis – industrial process emissions such nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride contribute to global warming

– indirect recycling outcomes are included - recycling displaces lower value materials with lower embodied energy, and hence lower embodied energy savings

[1] *WRAP, 2006, 'Environmental Benefits of Recycling: An international review of life cycle comparisons for key materials in the UK recycling sector', Waste & Resources Action Programme (WRAP), Oxon, accessed at http://www.wrap.org.uk/document.rm?id=2838, February 2007.*

- overseas databases are used – different energy sources from around the world have different carbon intensities. Thus the same amount of 'low carbon' energy use could lower the greenhouse intensity of a virgin product, and lower the net benefit from recycling in Australian conditions.

The above factors point to potential difficulties in using LCA as a tool for investigating potential greenhouse gas abatement, especially where software package models are used and the contributing elements to the abatement are not explicitly identified. A focus purely on energy savings, while having the disadvantage of not including non-energy emissions, nevertheless provides a robust starting point to investigate potential greenhouse gas benefits from increased recycling of container materials.

1.2 Overview of Report

This report presents the preliminary findings on the scale of the carbon abatement potential from the implementation of container deposits.

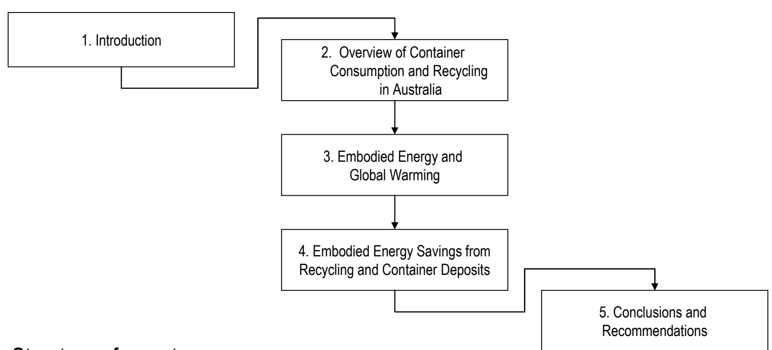

Figure 1 –Structure of report

The structure of the report is shown above in Figure 1. After this introduction, Section 2 provides an overview of container consumption, waste generation, recycling and disposal in Australia. Section 3 then provides an overview of the energy used to manufacture packaging materials and the associated links to greenhouse gas emissions and global warming. Section 4 then examines the savings in embodied energy that can be delivered through recycling packaging materials as opposed to manufacturing them from virgin sources. The potential energy savings are then translated into the potential carbon abatement arising from the implementation of a Container Deposit scheme in Australia. Finally Section 5 provides a summary of key conclusions and recommendations.

2 OVERVIEW OF CONTAINER CONSUMPTION AND RECYCLING IN AUSTRALIA

Packaging is a pervasive part of every day modern life. It is estimated that every year over three million tonnes of packaging is consumed in Australia.[2] Some of the issues with the amount of packaging used include the consumption of raw materials in production, the ratio of packaging to product, disposal of used packaging to landfill, and littering.

2.1 Container Consumption and Recycling

The majority of packaging is associated with fast moving consumer goods, such as soft drinks, confectionary, toiletries, detergents and other packaged food products. A readily identifiable subset of this packaging is containers, including containers for products like beverages, food items, and cleaning products. Materials of manufacture include glass, steel, aluminium, polyethylene terephthalate (PET), high density polyethylene (HDPE) and other plastic (including plastic film lined liquid paper board).

Australia consumed approximately 16 billion containers in 2005.[3] A breakdown of Australia's container consumption and recycling according to material type is presented in Table 1 below.

Table 1 – Overview of container consumption and recycling in Australia[4]

Material Type	*Tonnes of Containers*	*Average Container per Tonne*	*Estimated Consumption of Containers*	*Recycled Tonnes (net of contamination)*	*Recycling Rate*
Glass	850,000	4,784	4,066,400,000	300,000	35%
Steel	210,000	13,875	2,913,750,000	92,400	44%
Aluminium	46,000	66,821	3,073,766,000	29,000	63%
Polyethylene Terephthalate (PET)	118,000	29,205	3,446,190,000	42,000	36%
High Density Polyethylene (HDPE)	113,000	20,008	2,260,904,000	36,000	32%
Other plastic (including LPB)	15,000	24,060	360,900,000	2,000	13%
Total Containers	1,352,000		16,121,910,000	501,400	37%

[2] *Boomerang Alliance, 2004, 'National Packaging Covenant – Say No to the Waste Club', accessed at http://www.boomerangalliance.org/000_files/5_Say_No_to_the_Waste_Club.pdf, February 2006.*

[3] *West, D., 2006, 'Container Deposits – The Common Sense Approach', Boomerang Alliance, Sydney, accessed at http://www.boomerangalliance.org/000_files/Final_Container_Deposits___the_common_sense_approach.pdf, December 2006.*

[4] *Source in West 2006: 2005 data used for establishing targets for the NPC as agreed by multi-stakeholder groups (NPC Targets working group) including local gov't (WALGA, & MAV); Jurisdictions (NSW DEC, Vic EPA, & Federal DEH); Industry (ACOR, BIEC, PCA, AFCG) and Boomerang Alliance.*

2.2 Container Consumption and Recycling

The weight of the 16 billion containers consumed each year in Australia is estimated to be slightly more than 1.35 million tonnes. Although this represents only 4.1 per cent of the 32.8 million tonnes of waste generated each year in Australia,[5] it is significant in terms of the volume associated with the containers, and the frequency of interaction with disposal and recycling on a per capita basis.

For example, using approximate average contents sizes for the various packaging material types,[6] it is estimated that containers represent in excess of 7.9 million cubic metres of 'space', and thus occupy a significant place in consumer interactions with waste disposal and recycling. Furthermore, each person in Australia consumes approximately 800 containers each year, or nearly 16 per week. Thus consumption of containers is a daily experience for the Australian consumer.

Containers as a category also have a low recycling rate of 37 per cent. The disposal of 850,600 tonnes of packaging materials represents approximately 9.5 billion containers, or nearly 500 containers landfilled per person in Australia. This level of packaging consumption and disposal has a number of impacts that are presented in the following section.

[5] Derived from Hyder Consulting 2006, ''Waste and Recycling in Australia'', Department of Environment and Heritage, found at http://www.pc.gov.au/inquiry/waste/subs/sub103attachmenta.pdf, February 2007.

[6] Glass = 0.33l, steel = 0.4l, aluminium = 0.375l, polyethylene terephthalate (PET) = 0.75l, high density polyethylene (HDPE) = 0.75 l.

3 EMBODIED ENERGY AND GLOBAL WARMING

The manufacture and use of packaging creates a number of environmental impacts throughout the lifecycle of the packaging. One of the major impacts is associated with the energy requirements to manufacture the materials used in producing packaging (embodied energy). The amount of embodied energy in packaging materials is directly related to the carbon footprint of packaging. This in turn has implications for global warming. The life cycle stages, embodied energy, and carbon footprint of packaging materials are explored in further detail below.

3.1 Life Cycle Stages of Packaging

Some of the stages where the manufacturing and use of packaging creates an environmental impact are shown in Figure 2 below. Packaging is produced from materials such as glass, steel, aluminium, polyethylene terephthalate (PET), high density polyethylene (HDPE) and other plastic (including plastic film lined liquid paper board). These materials, in turn required many physical resources, in addition to energy and water for their manufacture. For example:

- glass – silica (sand), soda ash, limestone and feldspar
- steel – iron ore, coke, other additives eg. chromium for stainless and tin for tinplate
- aluminium – bauxite to refine alumina and alumina for aluminium smelting
- polyethylene terephthalate (PET) – ethylene glycol (from ethylene made from gas or oil) and terephthalic acid
- high density polyethylene (HDPE) - ethylene glycol (from ethylene made from gas or oil)

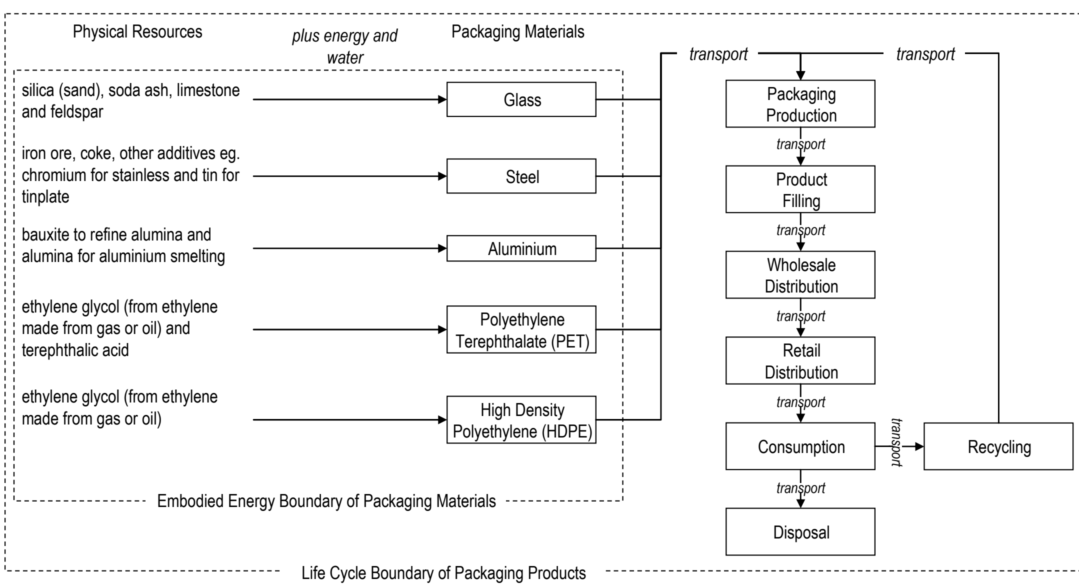

Figure 2 –Packaging materials and life cycle stages

3.2 Embodied Energy

Embodied energy is a measure of the amount of energy used to transform raw materials into a final product or material. For example, in the manufacture of aluminium, energy is used to mine bauxite, refine alumina, smelt into aluminium and then extrude, roll or cast into products (see Figure 2). Embodied energy is usually reported in standardised units of mega-joule per kilogram (MJ/kg) or giga-joules per tonne (GJ/tonne). The manufacture of one tonne of aluminium requires 206 GJ of energy. Some other estimates of the embodied energy of packaging materials are shown in Table 3 (Section 4).

When discussing embodied energy it is important to use gross energy figures. For example the amount of electricity (as measured in kilowatt hours - kWh, or megawatt hours MWh) used in the manufacturing process must be converted into the amount of energy that was used to generate the electricity in the first instance.[7] The actual embodied energy of a material will always be greater than the amount of electricity used because of the inefficiencies of converting heat into steam that drives turbines to generate electricity.

A distinction also needs to be made on whether a product or a material is being analysed. For example, the manufacture of an automobile or a household white-good involves a large amount of energy use in the product assembly. The embodied energy of the product will thus vary according to product type and the process of production, even if similar materials of manufacture are used. Because of this variety in product embodied energy levels, this analysis has been restricted to a comparison of the embodied energy of packaging materials of manufacture and excludes consideration of downstream packaging production (see Figure 2 for a graphical representation of boundary definition).

The majority of energy used in the manufacture of packaging materials is sourced from fossil sources such as oil, gas and coal. The link between energy use and global warming is summarised in the following section.

3.3 Global Warming

The Intergovernmental Panel on Climate Change (IPCC) has demonstrated that natural levels of greenhouse gases are being increased by human activity, including the burning of coal, oil, and natural gas for transport and energy purposes; from farming and changes in land use; and from other industrial processes. Computer climate models suggest that the increasing levels of greenhouse gases will cause global average temperatures to increase by 1.1 to 6.4°C by the year 2100, which will trigger irreversible and catastrophic changes to our weather and our planet.[8]

The economic implications of climate change were recently examined by the former chief economist of the World Bank, Sir Nicholas Stern. The report of the Stern Review 'The Economics of Climate Change'

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[7] One watt-hour is equal to 3,600 joules. A normal 60 watt light globe, left on for one hour will use 60 watt-hours of electricity, which is 216,000 joules (216 kilo-joules). However, the generation of electricity is only approximately 35% efficient. In other words, 35% of the energy in the coal is converted into electricity, This means that 617 kJ of coal would have needed to be burned to create the electricity to operated the light globe for one hour. In the case of embodied energy, the original energy value of the coal needs to be calculated for any electricity use in manufacture.

[8] IPCC 2007, 'Climate Change 2007: The Physical Science Basis Summary for Policymakers', Intergovernmental Panel on Climate Change, Geneva, found at http://www.ipcc.ch/SPM2feb07.pdf, February 2007.

concluded that 'climate change represents the greatest and widest-ranging market failure ever seen', and estimated the societal cost of climate change to be $110 per tonne of carbon dioxide equivalent (CO_2e).[9]

Greenhouse gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and several other industrial gases including hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). These gases trap heat energy from the sun within the atmosphere. Greenhouse gases differ in their ability to retain heat, and carbon dioxide is used as the reference gas, with greenhouse gases measured in terms of carbon dioxide equivalents (CO_2e). For example, methane is 23 times as potent a greenhouse gas as carbon dioxide. Hence 1 tonne of CH_4 is measured as 23 tonnes of CO_2e.[10]

In Australia nearly half of the 565 million tonnes of CO_2e emitted in 2004 came from stationary energy sources. Table 2 presents a breakdown by sources of Australian net emissions. The 'Waste' sector comprises 3.4 per cent of net national total greenhouse gas emissions, with solid waste emissions of 15.0 million tonnes of CO_2e and 4.1 million tonnes of CO_2e from liquid waste source. Solid waste emissions are caused by the decomposition of biologically degradable waste in landfill into landfill gas, which is approximately 50 per cent methane.

Table 2 – Australia's net greenhouse gas emissions[11]

Source	*$MtCO_2e$*
Stationary Energy	279.9
Transport	76.2
Fugitive Emissions	31
Industrial Processes	29.8
Agriculture	93.1
Land Use, Land Use Change and Forestry	35.5
Waste	19.1
Total	**564.7**

Container packaging materials (with the exception of liquid paperboard) do not decompose in landfills as they do not contain 'degradable organic carbon'. However, the landfilling of containers represents a lost opportunity to reduce greenhouse gas emissions through a saving in embodied energy. The relationship between embodied energy and greenhouse gas emission is discussed in the following section.

3.4 Embodied Energy and Greenhouse Gas Emissions

Energy use is directly related to greenhouse gas emissions. The greenhouse gas emissions per giga-joule of embodied energy is estimated by CSIRO as 0.098 tonnes of CO_2e.[12] Returning to the aluminium

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[9] *Stern Review, 2006, 'The Economics of Climate Change', HM Treasury, London, accessed at http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm, November 2006.*

[10] *Intergovernmental Panel on Climate Change found at http://www.ipcc.ch/*

[11] *AGO, 2006, 'Australian National Greenhouse Inventory 2004', Australian Greenhouse Office, Canberra, accessed at http://www.greenhouse.gov.au/inventory/2004/index.html, November 2006. Note that the 'net' refers to a reduction in greenhouse gas emissions from avoided land clearing.*

example from above, the manufacture of one tonne of aluminium (206 GJ) releases 20.2 tonnes of CO_2e. The disposal to landfill of that tonne of aluminium means that an additional 20.2 tonnes of $C0_2$e will be released in manufacturing a replacement tonne – a zero return on invested energy.

The Australian Council of Recyclers (ACOR) estimated that the embodied energy in all of the waste disposed of to landfill was 246,240,000 GJ, which equates to greenhouse gas emissions of 24.1 million tonnes of CO_2e (nearest 0.1 Mt).[13] This amount of 'embodied emissions' is more than one-and-a-half times as much as the annual emissions from fugitive landfill gas escaping landfill sites.

The recycling for reuse of container packaging materials uses less energy than manufacturing the same materials from virgin sources. Thus every giga-joule of energy saved through recycling represents an offset of fossilised energy generation, with a reduction (or abatement) in greenhouse pollution of 0.098 tonnes of CO_2e/GJ. The following section examines the carbon abatement (greenhouse gas reduction) potential from recycling materials used to manufacture containers.

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[12] *CSIRO (undated), 'Embodied Energy', CSIRO Manufacturing and Materials Technology, Sydney, accessed at http://www.cmit.csiro.au/brochures/tech/embodied, November 2006.*

[13] *ACOR, 2006, 'Productivity Commission Inquiry into Waste and Resource Efficiency Submission by Australian Council of Recyclers February 2006' Productivity Commission, Melbourne, accessed at http://www.pc.gov.au/inquiry/waste/subs/sub040.pdf, February 2007.*

4 EMBODIED ENERGY SAVINGS FROM RECYCLING AND CONTAINER DEPOSITS

The net difference in embodied energy between virgin materials and recycled materials translates into direct savings in greenhouse gas emissions with nearly 0.1 tonnes of CO_2e abated for every giga-joule of energy saved. This section presents indicative savings in embodied energy through the recycling of packaging materials and then explores the potential carbon abatement arising from increased recycling of containers through a Container Deposit scheme.

4.1 Embodied Energy Savings from the Recycling of Containers

The embodied energy of the major material groups used in container manufacture is presented in Table 3 below. Embodied energy 'abatement' is created when recycling uses less energy to reprocess packaging materials than is used to manufacture the same material from virgin feedstock. Each of the materials used to manufacture containers uses less energy when recycled, creating savings that range from 1.25 – 18.8 tonnes of CO_2e.

Table 3 – Comparison of virgin and recycled embodied energy values of materials used in container manufacture[14]

Material Type	*Virgin Materials Embodied Energy (GJ/tn)*	*GHG emissions per tonne of Virgin Material (tCO_2e)*	*Recycled Materials Embodied Energy (GJ/tn)*	*GHG emissions per tonne of Recycled Material (tCO_2e)*	*Net Energy Savings from Recycling (GJ/tn)*	*Net Abatement from Recycling (tCO_2e)*
Glass	22.5	2.21	9.74	0.95	12.76	1.25
Steel	34.7	3.40	7.32	0.72	27.38	2.7
Aluminium	206.0	20.19	14.1	1.38	191.90	18.8
Polyethylene Terephthalate (PET)	81.2	7.96	19.7	1.93	61.50	6.0
High Density Polyethylene (HDPE)	75.2	7.37	15.5	1.52	59.70	5.85

The energy used to recycle one tonne of aluminium is 14.1 giga-joules, compared to 206 giga-joules to manufacture one tonne of aluminium from virgin sources. The net saving in embodied energy from recycling one tonne of aluminium is thus 191.9 giga-joules, which equates to a greenhouse gas saving of 18.8 tCO_2e. To put this into a broader context, the recycling of one tonne of aluminium is equivalent to avoiding the burning of 7.1 tonnes of washed black coal.[15] In turn, if this coal was to generate electricity it would make 18.7 megawatt hours (MWh), enough electricity to run nearly 2.5 houses for one year.[16]

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[14] *Embodied energy values derived from Grant, T., James, K., Lundie, S., and Sonneveld, K., 2001, 'Stage 2 of the National Project on Life Cycle Assessment of Waste Management Systems for Domestic Paper and Packaging', RMIT, Melbourne, accessed at http://www.cfd.rmit.edu.au/content/download/123/836/file/Pkg&PapWaste2_Main_Report.pdf, December 2006.*

[15] *The calorific value (energy content) of washed black coal is 27 GJ/t - AGO, 2006, ' AGO Factors and Methods Workbook - For use in Australian greenhouse emissions reporting', Australian Greenhouse Office, Canberra, found at http://www.greenhouse.gov.au/workbook/pubs/workbook2006.pdf, February 2007.*

[16] *Assuming electrical efficiency of 35% and annual household energy usage of 8 MWh, approximately equally to 8 tonnes of CO_2e.*

4.2 Carbon Abatement Potential from Container Deposits

In order to estimate the carbon abatement potential from a container deposit scheme across Australia it is necessary to estimate the additional recycling that will result from container deposits and then apply material specific estimates of the greenhouse gas emission reductions that result from the savings in embodied energy.

Container Deposits refer to a market based instrument, backed up by government regulation, which provides a financial incentive for consumers to return their containers for reprocessing (the deposit is refunded at a collection depot, often an automated reverse vending machine). Usually a handling fee is also included in a container deposit scheme, effectively embedding the costs of collection into the price of a product. Container Deposit schemes are associated with high levels of recovery rates.[17]

For the purposes of this exercise it has been assumed that a 10¢ deposit would result in a 90 per cent collection rate of glass, steel, aluminium, PET and HDPE containers. This represents an increase of 53 per cent over the existing overall recycling rate for containers of 37 per cent, which is an additional 703,900 tonnes of recycling (see Table 1 in Section 2).

Table 4 – Carbon abatement potential from container deposit recycling[18]

Material Type	*Tonnes of Containers*	*CD Recycling*	*Less Existing Recycling*	*Net Additional Tonnes*	*Additional Energy Savings (GJ)*	*Net Greenhouse Abatement (tCO_2e)*
Glass Packaging	850,000	765,000	300,000	465,000	5,933,000	581,000
Steel Cans	210,000	189,000	92,400	96,600	2,645,000	259,000
Aluminium Bev Containers	46,000	41,400	29,000	12,400	2,380,000	233,000
PET Plastic	118,000	106,200	42,000	64,200	3,948,000	387,000
HDPE Plastic	113,000	101,700	36,000	65,700	3,922,000	384,000
Total Containers	1,337,000	1,203,300	499,400	703,900	18,828,000	1,844,000

The total embodied energy savings of 18,828,000 giga-joules translates to a greenhouse gas reduction of approximately 1.85 million tonnes of CO_2e. This additional greenhouse gas abatement from increased recycling through a Container Deposit scheme does not account for any increases in transport as a result of additional private trips to return CD materials to a collection depot or reverse vending machine, or for any additional transportation of recyclate. These impacts are considered in the following section.

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[17] For more information on container deposits in an Australian context see West, D., 2006, 'Container Deposits – The Common Sense Approach', Boomerang Alliance, Sydney, accessed at http://www.boomerangalliance.org/000_files/Final_Container_Deposits___the_common_sense_approach.pdf, December 2006.

[18] Embodied energy values and greenhouse abatement from Table 2 – note that other plastic has been excluded because of uncertainty around composition of containers.

4.3 Accounting for Transport

It has been argued that container deposit schemes result in net additional transport requirements because of additional personal trips to a container return point. Similarly increases in the transportation of recyclate for additional processing and/or delivery to end users could be offset by improvements in kerbside collection transport.[19] In spite of the rationale presented for no transport impacts from container deposits, namely that consumers are unlikely to undertake trips simply to dispose of containers and are likely simply to include them as part of a shopping, school drop-off, work or leisure excursion; and efficiencies generated by reduced kerbside collection, two sources of additional transport are considered here for the purposes of developing a robust net abatement estimate.

Starting with additional private trips for the purpose of returning CD materials to collection depots or reverse vending machines, the Institute for Sustainable Futures estimated that the highest amount of additional travel caused by a CD system would be an extra 22.7 kilometres per household per year.[20] Given that Australia has approximately 7.83 million households,[21] there would be a maximum additional 178 million kilometres of private travel each year. This amount of personal travel would release 52,220 tonnes of CO_2e.[22] However, this estimate is likely to be an overestimate as very few additional trips to return containers would be made outside of existing shopping, work, school drop-off or leisure excursions.

There would also be additional requirements to transport recyclate from the point of collection to a processing facility and/or end-user. A detailed materials stocks and flows analysis is beyond the scope of this study. For the sake of simplicity a transport distance of 1,000 kilometres has been assumed with a 20 tonne payload for all of the additional recycling collected through the CD system. This means that approximately 35 million kilometres will be travelled to transport the additional 703,900 tonnes of recyclate collected for further processing and delivery to end-users. This additional transport has an associated emission of 57,650 tonnes of CO_2e.[23] Again, this estimate is conservative in that it is an overestimate of transport impacts, especially as it fails to account for any reductions in transport emissions such as could be gained through improved efficiencies of collection in kerbside operations.

The potential emissions from additional transport arising as a result of a container deposit scheme is 110,000 tonnes of CO_2e (nearest 1,000 tonnes). This represents a reduced net benefit of 6 per cent, bringing the net abatement arising from the introduction of a CD scheme down from 1,844,000 tonnes of CO_2e, to 1,734,000 tonnes of CO_2e. On a per tonne basis this is an average reduction of 0.16 tonnes of CO_2e abated per tonne of CD material recycled, from 2.62 tonnes down to 2.46 tonnes of CO_2e.

However, it should be noted that the carbon impacts of transport are less that 6 per cent of the abatement estimate, and that the level of transport calculated is likely to be at least a twofold overestimate. If this

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[19] The removal of a large portion of containers from kerbside recycling collection will allow an increase in compaction rates, which in turn will reduce diesel consumption. In turn an increase in the amount of container recycling means a decrease in the amount of materials transported to landfill. As more landfills close are consolidated into 'super landfills' that are located outside of city boundaries, the reduced transport requirements from recycling could be significant.

[20] White, S. et al., 2001, 'Independent Review of Container Deposit Legislation in New South Wales, Volume II', Institute for Sustainable Futures, Sydney, accessed at http://www.isf.uts.edu.au/CDL_Report/Vol2/CDL_Vol2.pdf, February 2007.

[21] NEPC 2005, 'Reports from Jurisdictions on the Implementation of the Used Packaging Materials NEPM', as part of National Environment Protection Council annual report 2004 – 2005, Adelaide, accessed at http://www.ephc.gov.au/pdf/annrep_04_05/203_226_App_6_UPM_All.pdf, February 2007.

[22] Average passenger car fuel efficiency of 0.113 litres/kilometre means that 20,085 kilolitres of fuel would be used at a full fuel cycle emissions factor of 2.6 tCO_2e - AGO, 2006, ' AGO Factors and Methods Workbook - For use in Australian greenhouse emissions reporting', Australian Greenhouse Office, Canberra, found at http://www.greenhouse.gov.au/workbook/pubs/workbook2006.pdf, February 2007.

[23] The fuel efficiency of a large diesel truck is estimated at 0.546 litres per kilometre. Full fuel emissions factor of diesel is 3.0 tCO_2e - ibid, 2006.

overestimation was the case, it would bring the impacts of transport on the net abatement value from introducing container deposits down to 3 per cent, well within the margin of error for a preliminary estimate. In other words, the carbon impacts of additional transport do not significantly alter the carbon abatement value of a container deposit scheme.

5 CONCLUSIONS AND RECOMMENDATIONS

The materials of manufacture used in container packaging include glass, steel, aluminium, polyethylene terephthalate (PET), high density polyethylene (HDPE) and other plastic (including plastic film lined liquid paper board). Large amounts of energy are expended in the manufacture of these materials, causing significant amounts of greenhouse gas pollution. The recycling of packaging materials uses less energy than manufacturing from virgin resources. This saving of 'embodied energy' translates into direct savings in greenhouse gas emissions with nearly 0.1 tonnes of CO_2e abated for every giga-joule of energy saved. Thus effective mechanisms for increasing recycling can play an effective role in carbon abatement.

Container Deposits are one form of mechanism that can increase recycling rates of the products and materials that are included in the scheme. This increase in recycling presents a carbon abatement potential that is directly attributable to the CD scheme. In the Australian context, the introduction of 10¢ deposit on containers is estimated to increase recycling rates by 703,900 tonnes. The associated greenhouse gas reduction is estimated to be 1,844,000 tonnes of CO_2e. Accounting for potential increases in transport associated with the increase in recycling reduces the net abatement from a national CD system by 110,000 tonnes to 1,734,000 tonnes of CO_2e.

This level of carbon abatement is nearly 12 per cent of the national greenhouse gas emissions from solid waste. The energy saving is equivalent to the avoided burning of 655,000 tonnes of black coal, [24] and if used to generate electricity, would make 1,720 giga-watt hours, or enough electricity for nearly one quarter of a million homes.[25] Furthermore, this level of carbon abatement delivers the same reduction in greenhouse pollution as taking approximately 350,000 cars off the road.[26]

This preliminary investigation has identified that an increase in recycling of packaging materials is associated with a significant reduction in greenhouse gas emissions. It is recommended that the carbon abatement value of container deposits be included as part of any benefit and cost analysis of CD schemes.

[24] *Energy content (calorific value) of washed black coal at 27 GJ/tn from AGO, 2006, ' AGO Factors and Methods Workbook - For use in Australian greenhouse emissions reporting', Australian Greenhouse Office, Canberra, found at http://www.greenhouse.gov.au/workbook/pubs/workbook2006.pd, February 2007..*

[25] *This equation assumes an electrical efficiency of 35% and household electricity usage of approximately 8MWh per annum.*

[26] *The full fuel cycle greenhouse gas emissions for automotive gasoline (petrol) are 2.6 kg of CO_2e per litre of petrol. Average fuel efficiency is 8.85 km per litre. Assuming annual kilometres travelled of 17,000 gives 5 tonnes of CO_2e per car. AGO, 2006, ' AGO Factors and Methods Workbook - For use in Australian greenhouse emissions reporting', Australian Greenhouse Office, Canberra, found at http://www.greenhouse.gov.au/workbook/pubs/workbook2006.pdf, February 2007. This compares with other estimates of 4.3 (http://www.greenfleet.com.au/signup/subscribe.asp), 5.0 (http://www.climatefriendly.com) and 4.5 – 6.0 (http://shop.easybeinggreen.com.au/categories.asp?cID=7) tonnes of CO_2e per car.*