Hyder

Zero Waste South Australia

LCA of shopping bag alternatives

Final report

Hyder Consulting Pty Ltd
ABN 76 104 485 289
Level 16, 31 Queen Street
Melbourne VIC 3000
Australia
Tel: +61 3 8623 4000
Fax: +61 3 8623 4111
www.hyderconsulting.com

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Author	Kyle O'Farrell	
LCA review	Tim Grant (Life Cycle Strategies)	
Checker	Melanie Oke	
Approver	Peter Allan	

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This report has been prepared for Zero Waste South Australia in accordance with the terms and conditions of appointment for LCA of shopping bag alternatives dated May 2009. Hyder Consulting Pty Ltd (ABN 76 104 485 289) cannot accept any responsibility for any use of or reliance on the contents of this report by any third party.

This report has been independently reviewed, in line with the requirements of AS/NZS ISO 14 040. Further detail on the LCA modelling undertaken can be requested from Hyder Consulting by contacting Kyle O'Farrell on (03) 8623 4118, or at kyle.ofarrell@hyderconsulting.com.

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1 Introduction

1.1 Project background

South Australia has become the first jurisdiction in Australia to enact regulations banning lightweight single-use checkout bags (with some material based exceptions). The ban was enforced from 4 May 2009. The primary intention of the ban is to encourage the mass adoption of reusable bags over single-use plastic bags.

In 2007, Australians used 3.93 billion lightweight single use high density polyethylene (HDPE) bags. 2.96 billion of these came from supermarkets, while the others were used by; fast food restaurants, department stores, fashion retailers, convenience stores, liquor outlets and other retailers.

Table 1-1 Estimated HDPE bag consumption, 2002 to 2007 (Hyder 2008)

Year	No. of bags (billions)
2002	5.95
2003	5.24
2004	4.73
2005	3.92
2006	3.36
2007	3.93

The current rate of plastic shopping bag use and disposal is a significant concern within the Australian community. A study carried out by Roy Morgan in August 2004 found that 93% of Australians questioned were concerned about the impact that plastic bags had on the environment, and it seems reasonable to believe that this concern has not decreased more recently. The over consumption of plastic bags is an unnecessary use of resources, such as energy, water and materials. Plastic bags as litter create visual pollution problems and can have harmful effects on aquatic and terrestrial organisms.

In recent years, the consumption of plastic bags has generally trended downward, except for 2007, when a rebound in consumption occurred. This suggests that the behavioural change efforts by governments, major retailers, consumers and environmental organisations, are reaching a saturation point, and any further reductions in plastic bag consumption will require new approaches.

The switch away from lightweight single use HDPE carry bags has led to increased use in alternative forms of shopping bags manufactured from a wide range of materials. As a result, there are many different types of shopping bags being introduced into the Australian market at present, resulting in confusion for consumers and retailers about their environmental impacts and benefits.

In selecting preferred alternatives to single use HDPE plastic shopping bags there is a need to achieve an overall environmental gain.

1.2 Project scope

The objective of this study is to build upon and update the existing Australian life cycle assessment (LCA) data comparing the environmental impacts of shopping bags alternatives for carrying goods in Australia. This study is an update and expansion of a 2007 Sustainability Victoria (SV) commissioned report *Comparison of existing life cycle analysis of shopping bag alternatives* (Hyder 2007). The LCAs summarised for the SV report have been remodelled and updated with the most recently available data, and the life cycle impacts of a number of emerging shopping bag types have also been modelled for the first time.

This report aims to help retail decision makers and consumers choose between alternatives by informing them about the life cycle impact of alternatives to single use HDPE shopping bags and the environmentally preferred alternatives.

An overview of the LCA methodology and assumptions used in modelling the shopping bag alternatives has been provided in Section 3 of this report, to provide a context for the results. Appendix A of the report provides a comprehensive description of the LCA goal and scope, and of the life cycle inventory analysis and life cycle impact assessment phases of the modelling.

2 Types of single use and reusable shopping bags

The major single-use plastic bag types used in Australia are the:

- ‘singlet’ bag made of high density polyethylene (HDPE) – used mainly in supermarkets, fresh produce, convenience stores and take-away food outlets, and other non-branded applications.
- ‘boutique’ bag made of low density polyethylene (LDPE) – generally branded and used by stores selling higher value goods such as department stores, clothing and shoe outlets.

Most supermarket retailers also offer reusable non-woven plastic (polypropylene) ‘Green Bags’ and calico bags, for which they charge $0.50 – $2.00 per bag. Reusable bags made from alternative materials such as polyethylene terephthalate (PET) and nylon are also becoming more available.

The main types of shopping bags used in Australia and their key features are described below and summarised in Table 4-3. While there are other bag types on the market (e.g. jute), they are not used in significant numbers.

2.1.1 Single use high density polyethylene (HDPE) bags

HDPE is manufactured from ethylene, a by-product of gas or oil refining. Around 80% of HDPE bags consumed in Australia are imported from south-east Asia, where the primary source of polyethylene is oil. The primary hydrocarbon source for HDPE bags produced in Australia is natural gas.

These plastic bags offer a thin, lightweight, high strength, waterproof and reliable means of transporting shopping goods.

The major HDPE plastic shopping bag used in Australia is the ‘singlet’ bag. These bags are typically a non-branded bag, used mainly in supermarkets, take-away food and fresh produce outlets, but also in smaller retail outlets such as service stations and newsagents. Some HDPE bags are also used in a ‘wave top’ shape with a reinforced handle.

Major supermarket chains in Australia have established a ‘take-back’ recycling system at stores for used HDPE shopping bags. Drop-off bins are provided at the entry of many major supermarkets for used HDPE shopping bags, which are collected for recycling into new products.

2.1.2 Single use low density polyethylene (LDPE) bags

Like their HDPE counterparts, LDPE is manufactured from ethylene, a by-product of gas or oil refining. They offer a thin, lightweight, high strength, waterproof and reliable means of transporting shopping goods.

The LDPE 'boutique' style bags are generally branded and are used by stores selling higher value goods, such as department stores, clothing and shoe outlets.

No recycling program currently exists specifically for LDPE bags, however these bags can be recycled through the supermarket systems.

2.1.3 Single use (and multiple use) kraft paper bags

Kraft paper bags are mostly manufactured locally in Australia. Some Australian kraft paper bags contain up to 50% recycled content.

Pulping and bleaching processes involved in paper manufacture produce higher air emissions and waterborne wastes than plastics manufacture.

One of the major benefits of paper bags compared to plastics is that they are degradable and therefore have a shorter retention time and reduced impact in the litter stream. However, they also have a higher global warming potential if disposed to landfill, as they contribute to methane emissions due to the anaerobic decomposition of organic materials in landfills.

Paper bags are highly recyclable, with collection and recycling systems for paper now widespread in Australia.

2.1.4 Reusable non-woven polypropylene 'Green Bags'

Non-woven polypropylene 'Green Bags' are manufactured from polypropylene gas, a by-product of oil refining. They are strong and durable, and can hold significantly more than a conventional single use HDPE shopping bag.

These reusable bags usually have a sturdy removable base that is generally made from post-consumer plastic recyclate, which can be a mixture of multiple (recovered) polymer types. The base can also be manufactured from a range of virgin polymers such as nylon, polyethylene or PVC. There is significant variability in the composition, and source material, of these removable bases.

No recycling program currently exists for PP bags.

2.1.5 Reusable PET bags

While virgin PET resin is manufactured from terephthalic acid and ethylene glycol, products of oil refining, locally sold PET bags are generally made from recycled PET, sourced from applications such as soft-drink bottles.

PET bags are strong and durable, and can hold significantly more than a conventional single use HDPE shopping bag.

No recycling program currently exists for PET bags.

2.1.6 Reusable nylon bags

Woven nylon bags are manufactured from either virgin resin (a by-product of oil refining), or from what is assumed to be pre-consumer recyclate from industrial sources. They are strong and durable, and can hold significantly more than a conventional single use HDPE shopping bag.

These reusable bags usually have a sturdy removable base that is generally made from post-consumer plastic recyclate, which can be a mixture of multiple (recovered) polymer types. The base can also be manufactured from a range of virgin polymers such as nylon, polyethylene or PVC. There is significant variability in the composition, and source material, of these removable bases.

No recycling program currently exists for nylon bags.

2.1.7 Reusable calico bags

Calico bags are made from woven cotton and can be reused many times. They are strong, durable and flexible.

The cotton growing industry is a major consumer of synthetic fertilisers and pesticides. The labour conditions for bag manufacture in the developing world would be an issue that would warrant careful examination if these bags were to be utilised on a broad scale in Australia.

No recycling program exists for damaged calico bags at the end of their useful life, and while compostable, this would very rarely be an end-of-life destination for calico bags.

2.1.8 Single use degradable plastic bags

Plastic bags that can be broken down by chemical or biological processes are described as degradable. There are many different types and brands of degradable plastics currently present within or being introduced into the Australian market.

There are five general groupings of degradable polymers:

- Biodegradable polymers: capable of undergoing decomposition into carbon dioxide, methane, water, inorganic compounds or biomass in which the predominant mechanism is the enzymatic action of micro-organisms that can be measured by standardised tests, in a specified time, reflecting available disposal conditions.
- Compostable polymers: degradable under standard (usually commercial) composting conditions. To meet this definition they must break down under the action of micro-organisms (bacteria, fungi, algae), achieve total mineralisation (conversion into carbon dioxide, methane, water, inorganic compounds or biomass under aerobic conditions) and the mineralisation rate must be high and compatible with the composting process.

- Oxo-biodegradable polymers: undergo controlled degradation through the incorporation of 'prodegradant' additives (additives that can trigger and accelerate the degradation process). These polymers undergo accelerated oxidative defined degradation initiated by natural daylight, heat and/or mechanical stress, and embrittle in the environment and erode under the influence of weathering.
- Photodegradable polymers: break down through the action of ultraviolet (UV) light, which degrades the chemical bond or link in the polymer or chemical structure of the plastic. This process can be assisted by the presence of UV-sensitive additives in the polymer.
- Water-soluble polymers: dissolve in water within a designated temperature range and then biodegrade in contact with microorganisms.

While the definitions given above for biodegradable and compostable are very similar, the key difference is that while all compostable plastics are biodegradable, not all biodegradable plastics are compostable, in the sense of meeting the technical requirements of the Australian commercial composting standard AS 4736-2006. The Standard contains specific requirements for how quickly and completely a plastic breaks down in a typically commercial composting environment. It is also important to note some other key issues associated with the disposal of degradable plastic bags into commercial composting:

- The inclusion of biodegradable plastics (particularly films) in commercial composting may confuse consumers, resulting in increased contamination rates with non-degradable types of plastic.
- Plastic films can interfere with the processing of organic material by becoming entangled in shredders and other types of processing equipment.
- Biodegradable bags can contain non-degradable contaminates.

Additionally, it is highly possible that many bags that meet AS 4736-2006 (for commercial composting conditions), if disposed into home based composting, will fail to achieve the heat or moisture levels required to trigger degradation.

The actual material composition of degradable bags varies widely, with the main categories relevant to shopping bags presented in Table 2-2. Most of these polymers types could be expected to meet the commercial composting standard AS 4736-2006 when used in thin film applications, i.e. shopping bags.

Table 2-2 Types of degradable plastics used in shopping bags

Polymer type	Description	Modelled example
Starch / degradable polyester blends	Starch blended with polycaprolactone (PCL), a synthetic degradable polyester, or sometimes PLA. Generally about 45% starch.	Starch-polyester (PCL) bag
Renewable resource degradable polyesters	PLA (polylactic acid) – Lactic acid is produced via starch fermentation as a co-product of wet corn milling, with a further poly-condensation step to form PLA. PLA is often blended with starch to increase biodegradability and decrease cost.	PLA based bag
Starch based polymers	Manufactured from gelatinised plant starch. Usually 70%+ starch plus other additives.	High starch content bag that is 90% starch and 10% plasticisers
Oxo-biodegradable polymers	Often a polyethylene base, incorporating small quantities of prodegradant additives such as cobalt stearate or manganese stearate. Depending upon the oxo-biodegradable polymer type, this type of film may be less likely to meet the requirements of AS 4736-2006.	HDPE bag (97%) with prodegradant additives (3%)

Similarly to the HDPE shopping bags, degradable plastic bags are generally designed for a single use.

3 Life Cycle Assessment Methodology

3.1 Life cycle assessment

A life cycle assessment (LCA) provides a framework and methods for identifying and evaluating environmental impacts associated with the complete life cycle of products and services, i.e. from the product cradle to the grave. The basis of an LCA study is an inventory of all the inputs and outputs of industrial processes that occur during the life cycle of a product.

The life cycle of a product or service includes extraction of natural resources; production of raw materials; processing, manufacturing, and fabrication of the product; transportation or distribution of the product; and the disposal or recovery of the product after its useful life.

3.2 Streamlined LCA of shopping bag alternatives

A streamlined Life Cycle Assessment (LCA) has been undertaken by Hyder using the LCA software package SimaPro 7.1. It compared the life cycle environmental impacts of shopping bags alternatives for carrying goods in Australia: single-use materials (i.e. plastic, paper and degradable materials) and reusable bags made from plastics, paper and calico. Of the sixteen bags types modelled, eleven are updates of earlier modelling (CfD 2005), and five bags types are entirely new.

The LCA included production of the raw materials, manufacture of the bags, transport of the bags to the retailers, and disposal at the bags' end of life. Data used to model the bags was derived from existing published inventory information, discussions with bag suppliers, and direct measurement of key characteristics of bags.

Where available, Australian inventory data was used for energy production, some material production (e.g. PET and HDPE), transport, recycling and waste disposal. International public inventory data was used to model the remaining materials.

The modelled life cycles are based on specific sample bags, in use, to determine mass and material composition. Generic materials production and processing inventory data are then used as inputs to bag production. The bags assessed in this report are illustrative examples, it is acknowledged that other bags in the market will be made of the same materials, but will have differing characteristics and usage patterns. The bags modelled have been selected on the basis that they are the highly representative of their type in the market.

As the data contained in this report is the result of a streamlined LCA study using existing inventory data, rather than inventory data from the actual processes used for each specific bag. The results should be seen as reasonable indications of environmental performance, but are not the result of full LCA studies of each bag type.

3.3 Shopping bag life cycle

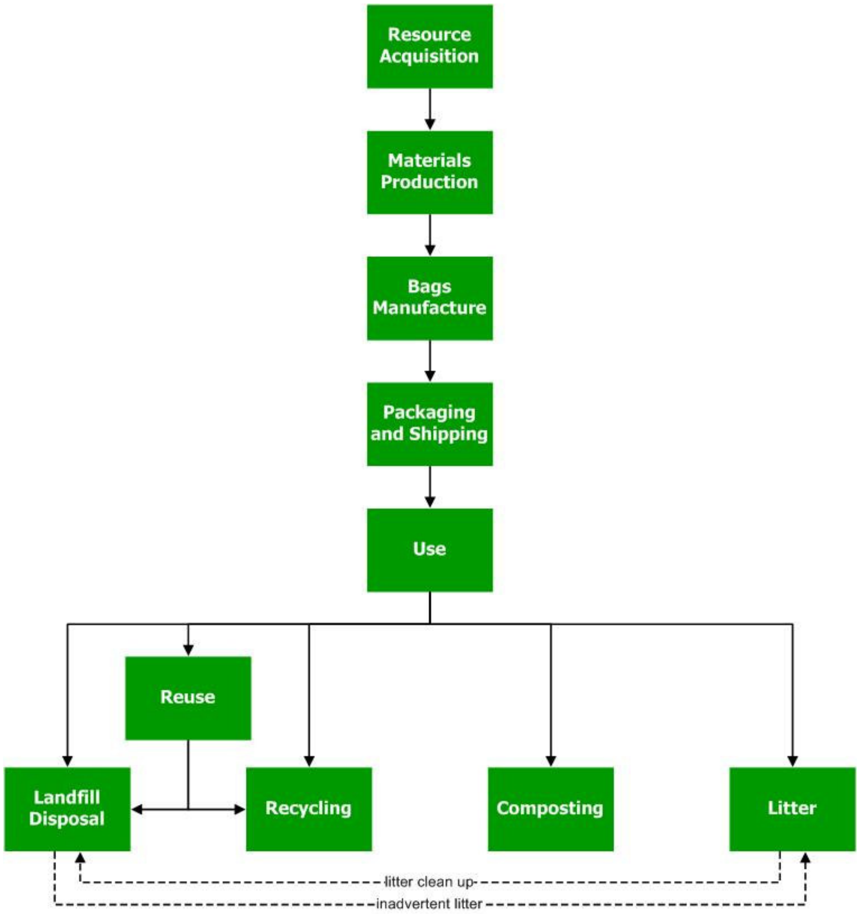

Figure 3-1 Generic life cycle of shopping bags[1]

3.4 Basis for the comparison

When comparisons of life cycle environmental impacts are performed, it is important that the products to be compared fulfil the same function. For the purpose of this study, the unit of comparison (functional unit) is defined as

> *The amount of shopping bags consumed by a household to carry 70 grocery items home from the supermarket each week for 52 weeks.*

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[1] Inadvertent litter is usually associated with windblown litter from disposal routes such as litterbins and landfill sites. Intentional litter results from inappropriate disposal actions by consumers.

3.5 Assumptions

Data on bag types relates to the most prominent example of each bag already in use in the Australian retail market.

To allow for size differences in bags, the assessment takes into account relative carrying capacity and expected life (see Table 4-3).

The assessment also takes into account any avoided impacts such as:

- avoided use of virgin polymer or paper fibre due to bag recycling programs
- avoided consumption of kitchen tidy bags as a result of bag reuse in the home.

Wherever possible, data is based on actual bag use, acknowledging that there is variability of each bag type in the marketplace.

Although relevant to all retail applications, the assessment is based on an application for supermarket use.

Alternatives have been modelled assuming 52 shopping trips per year with an equivalent shopping bag requirement of ten HDPE shopping bag loads each trip, corresponding to one HDPE bag per 6–8 items.

The manufacturing assessment of each shopping bag included the extraction of raw materials and the processing of them into the final product.

The transportation of each shopping bag was factored into the LCA. This included the international shipping of imported bags to Adelaide, as shown in Table 4-4. For South Australian road transportation to retailers, a distance of 80 km (Adelaide to point of use) in an articulated truck was used for all bag alternatives.

No allowance has been made for maintenance of reusable bags (e.g. washing) during the use stage.

Due to the variance in materials and expected life of many of the shopping bag alternatives, a number of end-of-life assumptions were factored into the LCA (Table 4-5). It should be noted that the analysis is highly dependent on assumptions made about reuse of bags; usage patterns of reusable bags; purchase of alternative products (e.g. kitchen tidy bags); and the percentage of bags entering the litter stream.

Table 4-3 Shopping bag types for assessment

Bag type	Features	Manufacturing process	Weight (g)	Relative capacity(1)	Expected life (# trips)	Bags per year(2)
Single use singlet plastic (HDPE) bag	Light, strong, durable, effective when wet, recyclable	Production of HDPE film from ethylene, a by-product of gas or oil refining	6	1	1	520
Single use singlet plastic (HDPE) bag with 100% recycled content	Light, strong, durable, effective when wet, contains recycled content, recyclable	Production of HDPE film from recycled post-consumer HDPE packaging	6	1	1	520
Reusable plastic (LDPE) bag (3 trips)	Light, strong, durable, effective when wet	Production of LDPE film from ethylene, a by-product of gas or oil refining	30.4	1.4	3	124
Single use kraft paper bag	Convenient, recyclable though the current kerbside system, manufactured from renewable resources	Production of kraft pulp from plantation and native timber fibre sources, plus proportion of recycled fibre from post-consumer sources. Production of liner and manufacture of paper bags.	44.2	1	1	520
Single use kraft paper bag with 100% recycled content	Convenient, contains recycled content, recyclable though the current kerbside system, manufactured from renewable resources	Production of pulp from post-consumer sources, production of liner and manufacture of paper bags.	44.2	1	1	520
Reusable kraft paper bag (2 trips)	Convenient, recyclable though the current kerbside system, manufactured from renewable resources	Production of kraft pulp from plantation and native timber fibre sources, plus proportion of recycled fibre from post-consumer sources. Production of liner and manufacture of paper bags.	44.2	1	2	260
Reusable kraft paper bag with 100% recycled content (2 trips)	Convenient, contains recycled content, recyclable though the current kerbside system, manufactured from renewable resources	Production of pulp from post-consumer sources, production of liner and manufacture of paper bags.	44.2	1	2	260
Reusable non-woven plastic	Strong, durable, effective when wet, reusable	Production of PP film from propylene gas, a by-	109	1.7	104	3

Bag type	Features	Manufacturing process	Weight (g)	Relative capacity[(1)]	Expected life (# trips)	Bags per year[(2)]
(polypropylene) 'Green Bag'		product of oil refining				
Reusable non-woven plastic (polypropylene) "Green Bag" with 100% recycled content	Strong, durable, effective when wet, reusable, contains recycled content	Production of PP film from recyclate	109	1.7	104	3
Reusable PET bags with 100% post-consumer recycled content	Strong, durable, effective when wet, reusable, contains recycled content	Production of PET fibre and weaving, from recyclate	48.6	1.4	104	4
Reusable nylon bags	Strong, durable, effective when wet, reusable	Production of nylon fibre from oil refining products, fibre production and weaving fabric	121.6	1.4	104	4
Reusable calico bag	Strong, durable, washable, reusable, manufactured from renewable resources	Cotton processing	85	1.4	104	4
Single use compostable starch-polyester blend (e.g. Mater-Bi)	Light, strong, compostable, biodegradable, manufactured from combination of renewable and non-renewable resources	Maize production, with PCL produced from cyclohexanone (95%) and acetic acid (5%)	8.1	1	1	520
Reusable starch bag (3 trips)	Strong, compostable, manufactured from renewable resources	Maize production, with plasticisers from oil refining by-products	25.2	1.1	3	158
Single use oxo-biodegradable bag (e.g. TDPA-EPI)	Light, strong, compostable, manufactured non-renewable resources	HDPE polymer and film manufacturing + cobalt stearate additive.	5.3	0.9	1	578
Single use polylactic acid (PLA) bags	Strong, compostable, manufactured from renewable resources	Maize production, with plasticisers from oil refining products"	8.1	1	1	520

(1) Relative capacity to a HDPE shopping bag.

(2) Quantity of shopping bags used to carry 70 grocery items home from the supermarket each week for 52 weeks in relation to relative capacity and adjusted in relation to expected life

Table 4-4 International transports of imported shopping bags

Bag type	Percentage imported[(1)]	Origin and distance travelled (km)
Single use singlet plastic (HDPE) bag	80	Hong Kong (8,300 km)
Single use singlet plastic (HDPE) bag with 100% recycled content	80	Hong Kong (8,300 km)
Reusable plastic (LDPE) bag (3 trips)	80	Hong Kong (8,300 km)
Single use kraft paper bag	0	Australian made
Single use kraft paper bag with 100% recycled content	0	Australian made
Reusable kraft paper bag (2 trips)	0	Australian made
Reusable kraft paper bag with 100% recycled content (2 trips)	0	Australian made
Reusable non-woven plastic (polypropylene) 'Green Bag'	100	Hong Kong (8,300 km)
Reusable non-woven plastic (polypropylene) "Green Bag" with 100% recycled content	100	Hong Kong (8,300 km)
Reusable PET bags with 100% post-consumer recycled content	100	Hong Kong (8,300 km)
Reusable nylon bags	100	Hong Kong (8,300 km)
Reusable calico bag	100	Pakistan (12,300 km)
Single use compostable starch-polyester blend (e.g. Mater-Bi)	100	Italy (17,300 km)
Reusable starch bag (3 trips)	100	Hong Kong (8,300 km)
Single use oxo-biodegradable bag (e.g. TDPA-EPI)	100	50:50 split between Hong Kong and Malaysia (7,800 km)
Single use polylactic acid (PLA) bags	100	50:50 split between USA and Japan (11,800km)

(1) The country of origin for different bags can be diverse and ever changing. For example, the ratio of HDPE bags from Australian sources had dropped from 50% in 2002 to 25% in 2006. At any time a supermarket may be sourcing a combination of local and imported bags. The country of origin identified in the table is therefore a best assessment of the likely sourcing profile.

Table 4-5 End-of-life assumptions

Bag type	Landfill %	Recycled % (1)	Composted %	Litter % (2)	Reuse % (3)
Single use singlet plastic (HDPE) bag	74.5	5	0	0.5	20
Single use singlet plastic (HDPE) bag with 100% recycled content	74.5	5	0	0.5	20
Reusable plastic (LDPE) bag (3 trips)	74.5	5	0	0.5	20
Single use kraft paper bag	39.5	60	0	0.5	0
Single use kraft paper bag with 100% recycled content	39.5	60	0	0.5	0
Reusable kraft paper bag (2 trips)	39.5	60	0	0.5	0
Reusable kraft paper bag with 100% recycled content (2 trips)	39.5	60	0	0.5	0
Reusable non-woven plastic (polypropylene) 'Green Bag'	99.5	0	0	0.5	0
Reusable non-woven plastic (polypropylene) "Green Bag" with 100% recycled content	99.5	0	0	0.5	0
Reusable PET bags with 100% post-consumer recycled content	99.5	0	0	0.5	0
Reusable nylon bags	99.5	0	0	0.5	0
Reusable calico bag	99.5	0	0	0.5	0
Single use compostable starch-polyester blend (e.g. Mater-Bi)	69.5	0	10	0.5	20
Reusable starch bag (3 trips)	69.5	0	10	0.5	20
Single use oxo-biodegradable bag (e.g. TDPA-EPI)	69.5	0	10(4)	0.5	20
Single use polylactic acid (PLA) bags	69.5	0	10	0.5	20

(1) Based on the current recycling industry it was assumed there would not be a recycling market for the reusable bags at end-of-life due to their relatively low volume. This is the subject of current developments and may change in the short to medium term.

(2) All bags were assumed to have 0.5% of total bags entering the litter stream at end-of-life. This percentage was based on available data relating to single use plastic (HDPE) bags entering the litter stream.

(3) Only single use plastic bag options were considered for reuse applications as it was assumed that the long life bags would be used for grocery shopping to the end of their functional life and would consequently be disposed of. It was estimated that 20% of available single-use plastic bags would replace the need for bin liners. This reuse as a bin liner for household waste results in avoided consumption of HDPE bin liner bags.

(4) Oxo-biodegradable bags usually abiotically disintegrate, rather than truly aerobically or anaerobically decompose into compost, as the conversion of carbon in the bag into carbon dioxide and biomass may not meet the requirements of the Australian Standard for biodegradable plastics AS 4736-2006.

3.6 Indicators

The LCA considered environmental impacts of the following types:

Material consumption	Material used in the manufacture of the bag (i.e. mass of the bag multiplied by the number consumed over one year).
Climate change	Climate change effects resulting from the emission of CO_2, methane or other greenhouse gases into the atmosphere. Greenhouse impacts are dominated by carbon dioxide through electricity and fuels consumption, methane emissions through degradation of materials in anaerobic conditions (e.g. landfill), and nitrous oxide (N_2O) emissions in fertiliser applications on crops.
Energy consumption	Total energy use including fossil fuel, renewable, electrical and feedstock (i.e. the energy embodied in a bag's material).
Water use	Water use including potable, process, cooling water.
Litter marine impacts	This indicator estimates the time in which litter in marine environments has the potential for ingestion or entanglement by marine fauna.
Litter aesthetics	This indicator attempts to represent the visual impact of litter, which was taken to be related to the area of the material and the time before it would degrade or be removed.

4 Results

The following table summarises the findings of the environmental assessment of shopping bag alternatives. A rating of one to five was used to show the diversity of impacts for each criterion, with one being the lowest impact. Impacts cannot be added together to produce an overall bag rating.

Table 4-6 Environmental impacts of shopping bags over the full life cycle of the bag

Bag type	Example	Material consumption	Climate change	Energy consumption	Water use	Litter marine impacts	Litter aesthetics	Potential beneficial disposal options
Single use singlet plastic (HDPE) bag		♣♣♣	♣♣	♣♣	♣	♣♣♣♣♣	♣♣♣♣♣	Recycle at major supermarkets / Reuse as a garbage bin liner with disposal to landfill
Single use singlet plastic (HDPE) bag with 100% recycled content		♣♣♣	♣	♣	♣	♣♣♣♣♣	♣♣♣♣♣	Recycle at major supermarkets / Reuse as a garbage bin liner with disposal to landfill
Reusable plastic (LDPE) bag (3 trips)		♣♣♣♣	♣♣	♣♣♣	♣	♣♣♣♣♣	♣♣♣♣♣	Recycle at major supermarkets / Reuse as a garbage bin liner with disposal to landfill
Single use kraft paper bag		♣♣♣♣♣	♣♣♣♣♣	♣♣♣♣♣	♣♣♣	♣	♣♣♣	Recycle in household recycling bin
Single use kraft paper bag with 100% recycled content	Photo unavailable	♣♣♣♣♣	♣♣♣♣♣	♣♣♣♣♣	♣♣	♣	♣♣♣	Recycle in household recycling bin

Bag type	Example	Material consumption	Climate change	Energy consumption	Water use	Litter marine impacts	Litter aesthetics	Potential beneficial disposal options
Reusable kraft paper bag (2 trips)		♣♣♣♣♣	♣♣♣♣♣	♣♣♣♣♣	♣♣	♣	♣♣	Recycle in household recycling bin
Reusable kraft paper bag with 100% recycled content (2 trips)	Photo unavailable	♣♣♣♣♣	♣♣♣♣♣	♣♣♣♣	♣♣	♣	♣♣	Recycle in household recycling bin
Reusable non-woven plastic (polypropylene) 'Green Bag'		♣	♣	♣	♣	♣♣	♣	None - disposal to landfill
Reusable non-woven plastic (polypropylene) "Green Bag" with 100% recycled content		♣	♣	♣	♣	♣♣	♣	None - disposal to landfill
Reusable PET bags with 100% post-consumer recycled content		♣	♣	♣	♣	♣	♣	None - disposal to landfill
Reusable nylon bags		♣	♣	♣	♣♣	♣♣♣	♣	None - disposal to landfill

Bag type	Example	Material consumption	Climate change	Energy consumption	Water use	Litter marine impacts	Litter aesthetics	Potential beneficial disposal options
Reusable calico bag		♣	♣	♣	♣♣♣♣♣	♣	♣	None - disposal to landfill
Single use compostable starch-polyester blend (e.g. Mater-Bi)	Photo unavailable	♣♣♣♣	♣♣	♣♣♣	♣♣	♣♣♣	♣♣♣	Commercial compost / Reuse as a garbage bin liner with disposal to landfill
Reusable starch bag (3 trips)		♣♣♣♣	♣♣	♣♣	♣♣	♣♣♣	♣♣♣	Commercial compost / Reuse as a garbage bin liner with disposal to landfill
Single use oxo-biodegradable bag (e.g. TDPA-EPI)		♣♣♣	♣♣♣	♣♣♣	♣♣	♣♣	♣♣♣	Reuse as a garbage bin liner with disposal to landfill
Single use polylactic acid (PLA) bags	Photo unavailable	♣♣♣♣	♣♣	♣♣♣	♣♣♣	♣♣♣	♣♣♣♣	Commercial compost / Reuse as a garbage bin liner with disposal to landfill

5 Key findings

- Reusable bags have lower environmental impacts than **all** of the bags with only 1–3 typical uses
- A substantial **shift to more durable bags** would deliver environmental gains through reductions in greenhouse gases, energy and water use, resource depletion and litter.
- The **reusable PET bag with 100% post-consumer recycled content** was found to achieve the greatest environmental benefits, closely followed by the **non-woven plastic (polypropylene) 'Green Bag'**
- The **shift from one single use bag to another single use bag** may improve one environmental outcome, but be offset by another environmental impact. As a result, no single-use bag produced an overall benefit.
- **Recycled content** in bags generally led to lowering the overall environmental impact of bags
- From a **climate change** perspective the paper bags performed most poorly, due in large part to their relatively high weight

Average household savings from switching to reusable 'Green Bags'

There is significant potential to reduce life cycle environmental impacts of plastic bag usage in the form of resource consumption, climate change impacts, energy, water and litter.

By taking commonly available reusable non-woven polypropylene 'Green Bags' when going shopping, South Australian households can make a significant contribution to reducing greenhouse gas emissions, conserving energy and reducing litter impacts. Overall water impacts are similar for both the HDPE and PP bags.

Table 5-7 South Australian annual environmental savings from switch to reusable 'Green Bags"

Greenhouse	4,224 tonnes of greenhouse gas emissions abated	Which is equivalent to not releasing over 4.3 million black balloons of greenhouse pollution into the atmosphere[1]
Energy	12 million megajoules of energy saved	Which is equivalent to powering each households TV for 1.6 months[2]
Litter marine impacts	Approximately 8,000 kg of avoided marine litter	-

[1] 1 black balloon = 50 grams of carbon dioxide (Sustainability Victoria, 2006)

[2] The average television in Australia could be expected to consume around 80 kWh per year in on-mode and around a further 30 kWh per year in standby mode (Harrington *et al.*, 2006). 1 kWh = 3.6 MJ (Sustainability Victoria, 2007), with a 30% conversion efficiency of thermal energy into electricity.

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Appendix A

Life cycle assessment – detailed description

A1 Introduction to detailed description of goal and scope

A1-1 Objective of this document

The primary objectives of this goal and scope definition document are to:

- determine the goal and scope of the Life Cycle Assessments on the following types of plastic bag:
  - 100% post-consumer recycled content PET bags
  - nylon bags
  - 100% post-consumer recycled content green (PP) bags
  - polylactic acid (PLA) bags
  - high starch content bags.
- outline the LCA process
- propose the modelling approach and the indicators which will be reported upon
- propose a functional unit for the LCA.

The goal and scope definition phase is important because it determines why an LCA is being conducted (including the intended use of the results) and describes the systems to be studied, and the data categories to be studied. The purpose, scope and intended use of the study influence the direction and depth of the study, addressing issues such as the geographical extent and time horizon of the study, and the quality of the data that is necessary (AS/NZS ISO 14041:1999).

A1-2 Background to project

South Australia has become the first jurisdiction in Australia to enact regulations banning lightweight checkout bags. The ban was enforced from 4 May 2009.

The intention of the ban is to encourage the mass adoption of reusable bags as alternatives to lightweight plastic bags.

This project will expand the suite of publicly available life cycle assessments of shopping bag alternatives, by assessing the five emerging shopping bag forms (listed above).

A1-3 Objective of this study

The objective of the LCAs is to determine the environmental impact of the manufacture and use of the modelled plastic bags. The assessment will consider the complete life-cycle, including extraction of raw materials, production processes, transport and end-of-life management options.

The LCA study will provide ZWSA with sound information to determine the environmental credentials of the assessed plastic bag types.

The environmental impact of the plastic bags will be compared across the following seven indicators:

- material consumption
- climate change
- energy use
- water use
- marine litter impacts
- litter aesthetics

The results build upon, and are presented in a format that is consistent with the 2007 Sustainability Victoria report "*Comparison of existing life cycle analysis of shopping bag alternatives*". The SV report summarised prior LCA modelling for eleven bag types undertaken by Centre for Design at RMIT University. The prior modelling for these eleven bags has also been updated as part of this current project.

A2 Goal of the study

A2-1 Intended application of the study

The goal of this study is to assess the respective environmental impacts of the modelled plastic bag types. In addition, the pre-existing LCA modelling for the eleven bag types reporting upon in the SV (2007) report have also been updated, where improved data is now available.

The results are a comparative assertion between the different bag types, and are intended to be disclosed to the public.

As this is a public study, it has undergone review by an external reviewer, in accordance with AS/NZS ISO 14040.

A2-2 Reasons for carrying out the study

The reasons for carrying out the study are to:

- communicate to a wide audience the comparative environmental impacts of the different bag types
- inform the environmental case for undertaking the single use plastic bag ban.

A2-3 Intended audience of the study

The intended audience for this study consists of:

- decision makers within ZWSA
- wider government and the general community

- retailers.

A3 Scope of the study

A3-1 Function of the product systems under study

The function of the modelled shopping bags is to carry groceries from a store (supermarket) to home.

A3-2 Functional unit

A common functional unit is required to allow comparison between the different types of shopping bag. For the purpose of this study, the ‘functional unit’ is defined as:

> *The quantity of shopping bags consumed (kg) by a household carrying 70 grocery items home from a supermarket each week, for 52 weeks.*

A3-3 Product system descriptions

See Section 3.5 of the main report.

A3-4 System boundaries

The generalised life cycle system boundary is outlined in Figure . Within the 'Use' phase the transport of the shopping and bags is assumed to be the same for all options and is therefore excluded.

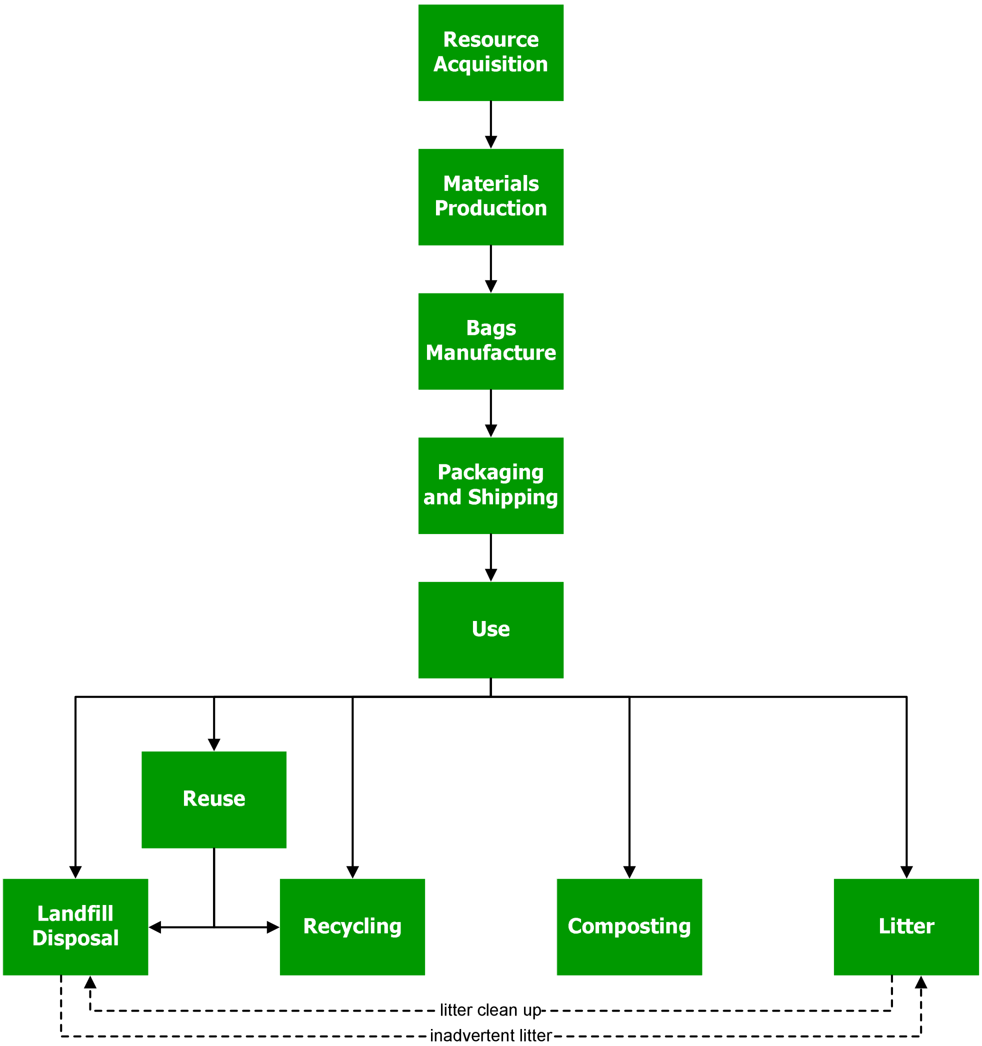

Figure A-1 Generic life cycle of plastic bags

The assessment also takes into account any avoided impacts such as:

- avoided use of virgin polymer or paper fibre due to bag recycling programs
- avoided consumption of other bags (e.g. kitchen tidy bags) as a result of (single use) shopping bag reuse in the home.

Although relevant to all retail applications, the assessment is based on an application for supermarket use.

The manufacturing assessment of each shopping bag included the extraction of raw materials and the processing of them into the final product. For imported bags, overseas inventory data specific to the country of origin was used where possible.

In line with the requirements of AS/NZS ISO 14044, life cycle stages, unit process and flows across the following areas will be incorporated into the systems and subsequent modelling:

- inputs and outputs for the main manufacturing/processing sequences
- distribution/transportation
- production and use of fuels, electricity and heat
- disposal of process wastes and products
- recovery of used products (including reuse, recycling and energy recovery).

The following areas have not been incorporated into the systems and subsequent modelling:

- the general manufacture, maintenance and decommissioning of capital equipment (except for the third order impacts relating to transport, e.g. truck manufacture)
- use and maintenance of products
- the manufacturing impacts of some ancillary materials (ancillary inputs are material inputs that do not constitute a part of the final product) have been excluded (assumed below the 1% cut-off)
- additional operations, such as lighting and heating.

The system boundaries for this LCA study are generally second order for both materials and energy, with all significant second order life cycle processes incorporated into the modelling.

A3-5 Allocation and coproduction

Allocation is "partitioning the input or output flows of a unit process to the product system under study" (AS/NZS ISO 14040). For example, the use of transport fuels involves energy allocations between petrol, diesel and gas production, and other refinery products.

Generally, no allocation is incorporated into the modelling, except where it is accounted for in underlying processes, such as fuel production. In alignment with the LCA Standards, system expansion is preferentially applied over allocation wherever possible, through disaggregation of the product system and the use of system boundary expansion. In particular, recycling and reuse are modelled using system boundary expansion.

A3-6 Life cycle impact assessment phase

Objective

The objective of the life cycle impact assessment (LCIA) phase of this study is to provide comparative analysis around the environmental impacts resulting from the inventory results for the modelled systems. The aim is to provide a comparison of the different environmental effects using impact categories that address the main environmental impacts of the modelled product systems (i.e. are relevant to the product systems), and present the results in an accessible format that is consistent with SV (2007) report.

Outlined here is the identification of the impact categories, related category indicators and characterisation approaches that this LCA study will use.

The following steps are undertaken within this study:

- selection of impact categories (and related category indicators) and characterisation models
- classification – the assignment of LCI results
- characterisation – the calculation of inventory burdens potential contribution to impacts.

Impact assessment methods are described in AS/NZS ISO 14044. Obligatory elements such as classification and characterisation will be addressed in this study. Normalisation, ranking and weighting (optional elements) have been excluded in compliance with AS/NZS ISO 14044 requirements for comparative assertions which may be disclosed to the public

Selection of impact categories

Selection of appropriate impact categories is an important step in an LCA. For this study the impact categories (and proxy impact categories, e.g. water use) were selected to cover selected key environmental issues (e.g. material consumption, climate change, water and energy use, and litter) that were consistent with prior work in this area, and seemed particularly relevant to the objectives of this project.

Table A-1 Impact categories and calculation methods

Impact category	Unit	Description	Calculation method
Material consumption	kg	Material used in the manufacture of the bag (i.e. mass of the bag multiplied by the number consumed over one year).	N/A
Climate change	kg CO_2 eq	Climate change effects resulting from the emission of CO_2, methane or other greenhouse gases into the atmosphere. Greenhouse impacts are dominated by carbon dioxide through electricity and fuels consumption, methane emissions through degradation of materials in anaerobic conditions (e.g. landfill), and nitrous oxide (N_2O) emissions in fertiliser applications on crops.	IPCC 2007 GWP 100a
Energy consumption	MJ LHV	Total energy use including fossil fuel, renewable, electrical and feedstock (i.e. the energy embodied in a bag's material).	Addition of energy inputs
Water use	kL H_2O	Net water use including potable, process, cooling water. Water quality, water depletion, biodiversity.	Addition of direct water uses
Litter marine impacts	g.yr	This indicator estimates the time in which litter in marine environments remains in ocean prior to breaking down into particle sizes that do not pose an entrapment danger to larger marine organisms, either in the water column or on the sea floor. ▪ light plastics (e.g. single use HDPE and LDPE bags, but not degradable polymers) – one years ▪ heavy plastics (e.g. PP, PET and nylon bags) – two years ▪ paper and degradable polymers – 1 day to three months ▪ calico – six months.	N/A
Litter aesthetics	m^2.yr	This indicator attempts to represent the visual impact of litter, which was taken to be related to the areas of the material and the time before it would degrade. To model this indicator an estimate of the average time a piece of litter may remain in the litter stream was needed. The proposed data to be used for different materials is as follows: ▪ light plastics (e.g. single use HDPE and LDPE bags, but not degradable polymers) – two years ▪ heavy plastics (e.g. PP, PET and nylon bags) – five years ▪ paper and degradable polymers – six months ▪ calico – two years.	N/A

Assumptions

Important general assumptions used throughout the life cycle modelling include:

- Wherever possible, data is based upon actual bag use, however it is acknowledged that there is variability of use for each bag type in the marketplace.
- Although relevant to all retail applications, the assessments are based on assumed bag use in supermarkets.
- Alternatives have been modelled assuming 52 shopping trips per year with the number of bag loads each trip dependent upon the capacity of each bag type.
- The manufacturing assessment of each shopping bag included the extraction of raw materials and the processing of them into the final product. For imported bags, overseas inventory data specific to the country of origin was used where possible.
- The transportation of each shopping bag was factored into the LCA. This included the international shipping of imported bags to Australia (place of departure to Adelaide. For Australian transportation to retailers in SA, a distance of 80 km in a 28 tonne articulated truck was used for all bag alternatives.
- No allowance has been made for maintenance of bags (washing and ironing) during the use stage.

Due to the variance in materials and expected life of many of the shopping bag alternatives, a number of end-of-life assumptions were factored into the LCA. It should be noted that the analysis is highly dependent on assumptions made about reuse of bags; use patterns of reusable bags; purchase of alternative products (e.g. kitchen tidy bags); and the percentage of bags entering the litter stream.

Cut-off

Very approximately, inputs and outputs were included in the life cycle modelling occurred where they were likely have an impact of 1% or more on the overall environmental burden of the life cycle of the shopping bags.

A3-7 Inclusions and exclusions

Capital equipment

Generally the impacts of capital equipment are low compared with the direct use elements of the life cycles. For this reason, and due to resourcing limitations, capital equipment impacts have generally not been incorporated into the models. The one exception to this is for freight transport, where pre-existing Australian data was readily available.

Workforce burdens

It is not common practice when undertaking LCAs to include an assessment of human labour burdens (impacts), due to difficulties in allocation, drawing boundaries, obtaining data and differentiating between labour and capital equipment. Human labour has been excluded and is outside of the scope and resources available for this study.

A3-7 Ranking system and numerical results summaries

The numerical modelling results were converted to a simple 'club' indicator (Table 4-6) using the same environmental impacts rating system as that used in the previous SV (2007) report. This is reproduced in Table A-2 below.

Table A-2 Environmental impacts rating system

Number of 'clubs'	Material consumption		Greenhouse (global warming)		Cumulative energy demand		Water use		Litter Marine Impacts		Litter Aesthetics	
	kg		kg CO_2		MJ		kL H_20		g.y		m^2.y	
	Min value	Max value	Min value	Max value	Min value	Max value	Min value	Max value	Min value	Max value	Min value	Max value
1	0.00	1.25	0.0	5.0	0.0	100	0	50	0.0	2.0	0.00	0.05
2	1.25	2.50	5.0	10.0	100	200	50	200	2.0	4.0	0.05	0.10
3	2.50	3.75	10.0	15.0	200	300	200	500	4.0	6.0	0.10	0.15
4	3.75	5.00	15.0	20.0	300	400	500	1000	6.0	8.0	0.15	0.20
5	5.00	>	20.0	>	400	>	1000	>	8.0	>	0.20	>

The actual numerical LCA modelling results are presented in Table A-3.

Table A-3 Numerical LCA modelling results

Bag type	Climate change kg CO_2 eq	Cumulative energy demand MJ LHV	Water use litres	Litter marine biodiversity g.y	Litter aesthetics m^2a
Single use singlet plastic (HDPE) bag	6.17	199.77	4.22	15.60	0.62
Single use singlet plastic (HDPE) bag with 100% recycled content	3.25	14.74	3.40	15.60	0.62
Reusable plastic (LDPE) bag (3 trips)	8.94	269.16	5.11	18.82	0.28
Single use kraft paper bag	61.12	865.10	349.97	0.34	0.12
Single use kraft paper bag with 100% recycled content	56.32	648.50	167.50	0.34	0.12
Reusable kraft paper bag (2 trips)	30.56	432.55	174.98	0.17	0.06
Reusable kraft paper bag with 100% recycled content (2 trips)	28.16	324.25	83.75	0.17	0.06
Reusable polypropylene 'Green Bag'	0.80	23.15	20.71	3.21	0.01
Reusable polypropylene "Green Bag" with 100% recycled content	0.41	7.16	23.62	3.21	0.01
Reusable PET bags with 100% post-consumer recycled content	0.51	8.01	16.25	1.74	0.01
Reusable nylon bags	2.40	40.31	198.37	4.34	0.01
Reusable calico bag	3.20	30.05	7600.36	0.76	0.01
Single use compostable starch-polyester blend (e.g. Mater-Bi)	9.03	210.44	91.35	5.27	0.12
Reusable starch bag (3 trips)	7.54	178.08	99.06	4.96	0.11
Single use oxo-biodegradable bag (TDPA-EPI)	10.24	229.71	75.73	3.83	0.14
Single use polylactic acid (PLA) bags	7.01	267.34	236.03	5.27	0.16