# Environmental impacts of shopping bags

Ref number: SPA1039WOW-01

## Report for:
## Woolworths Limited

## by:
## The Sustainable Packaging Alliance Limited

**ABN 48 127 905 024**

sustainablepack.org

31st March 2009

**Revised 30 April 2009**

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The Sustainable Packaging Alliance, RMIT University, Birubi Innovation and Helen Lewis Research confirm that the report results expressed here have been check for consistency and draw on the datasets available to the researchers at the time of the analysis. The results should only be viewed in the context in which they are presented, and no external peer review has been undertaken. Accordingly, the authors will not accept any liability for consequential damage suffered by it in any way relating to the Deliverables or provision of the Services.

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## Glossary of terms

| | |
|---|---|
| $CO_2$ | Carbon dioxide |
| $C_2H_4$ | Methane |
| EPHC | Environment Protection and Heritage Council |
| GJ | Giga joules |
| $H_2O$ | Water |
| HDPE | High density polyethylene |
| KG | Kilograms |
| KL | Kilolitres |
| L | Litres |
| LHV | Low heat value |
| LLDPE | Linear low density polyethylene |
| LDPE | Low density polyethylene |
| M | Metres |
| MJ | Mega joules |
| PBAT | Polybutylene adipate terephthalate |
| PBS/A | Polybutylene succinate/adipate |
| PCL | Polycaprolacton |
| PET | Polyethylene terephthalate |
| PLA | Polylactic acid |
| $PO_4$ | Phosphates |
| PP | Polypropylene |

## Executive Summary

This report provides an assessment of the environmental impacts of 7 alternative shopping bags used by retailers:

- high density polyethylene (HDPE) plastic with 100% virgin material;
- HDPE plastic with 15% recycled material;
- compostable plastic bag;
- oxo-degradable plastic bag;
- paper bag;
- reusable polyethylene terephthalate (PET) bag with recycled material; and
- reusable polypropylene (PP) bag.

A life cycle approach was used because it considers the environmental impacts of a shopping bag from 'cradle to grave' rather than at a single point in the supply chain. It also considers a range of environmental impact categories, rather than focusing on a single environmental issue. Focusing on a single point in the supply chain, or a single impact category, can produce a result that simply shifts the environmental burden from one area to another. A life cycle approach assists decision-makers to consider the broader impacts of a particular action.

A streamlined Life Cycle Assessment (LCA) was undertaken for the 7 alternative bags. The study is referred to as a 'streamlined LCA' because it used existing data in SimaPro software rather than data from the actual processes used for each specific bag. The results are therefore indicative only.

The life cycle which was modelled includes the environmental impacts associated with raw material sourcing and production, manufacture of the bags and their disposal at end of life (i.e. landfill, recycling, compost or litter). A qualitative review of disposal and recovery options for each bag was also undertaken.

The key outcomes of the life cycle assessment review were:

1. Generally, the reusable bags (PET and PP) have lower environmental impacts than all of the single use bags. These findings are consistent with previous studies and illustrate the benefits that can be achieved when reusing an item for the same application.
2. The benefits of a reusable bag are highly sensitive to the number of times each bag is used during its life. For example, if a reusable PP 'green bag' is only used 52 times (weekly for a year) instead of the assumed 104 times (weekly for 2 years) then its impact on global warming is higher than the impact of each of the single-use bags except the paper bag. The implication for retailers is that consumers should be encouraged to reuse existing bags rather than continuously buying new bags.
3. The PP reusable bag has a lower impact than the PET reusable bag for all of the impact categories except two (solid waste and fossil fuels), assuming that both types of bags are durable enough to be reused at least 104 times.
4. The 'best' or 'environmentally preferred' single use bag varies depending on the environmental impact category being considered.
5. Overall the single use paper bag has the highest environmental impact as a result of pulp and paper production and the weight of material required per bag. The single use paper bag has the highest impact, or equal highest impact, for all categories except eutrophication. For most impact categories this result does not change if the bag is reused again (i.e. used for 2 shopping trips) but its relative ranking on solid waste does improve

significantly, from the equal highest impact (along with recycled HDPE and the PP reusable bag), to the second lowest impact.

6. Global warming impacts are driven by material resource consumption and energy use across the life cycle. The heavier the bag the more resources are required, which has flow on effect on material extraction processes and energy consumption. The reusable bags score the lowest impact for this category because over a 12 month period total consumption of bag material is only 200 grams (PET bag) and 460 grams (PP bag) compared with 4 kg (HDPE bag) and 24.4 kg (paper bag).

7. Water use impacts are driven by water consumption in material production. Greater volumes of water are consumed in pulp and paper production than for any of the other materials, hence the paper bag option shows the greatest impact on this measure.

8. Solid waste impacts are the lowest for the compostable bag and PET reusable bag and similar for most other bag options.

9. Raw materials sourced from land-based operations have higher impacts for eutrophication (the release of nutrients into waterways) and land use (the occupation of land to grow crops and timber). The compostable bag has the highest eutrophication impact, which is approximately 70 times greater than the eutrophication impact of the other bag options with the exception of the paper bag (the compostable bag is approximately 7 times greater than the paper bag). The paper bag has the greatest impact on land use, significantly larger than all other bag materials.

10. Paper bags have the lowest impact in litter. Single use HDPE bags and paper bags make up a small percentage of littered items (both less than 1% according to Keep Australia Beautiful (2008)). However, HDPE bags tend to have a higher impact because they are more visible and take longer to break down in the environment. They can also potentially cause injury to animals and wildlife if ingested. Compostable and oxo-degradable plastic bags are likely to break down at a faster rate than conventional HDPE bags but there is limited data available on how long degradation would take in different environments (e.g. soil, marine water, fresh water). The environmental impact of the prodegradant additive in oxo-degradable bags, which is based on heavy metal compounds, is also unknown.

11. All of the bags have potential to be recovered at end of life rather than disposed to landfill. Whether or not they are *actually* recovered depends on 3 things: the material the bag is made from, the infrastructure available for collection and reprocessing, and the willingness of consumers to dispose of the bag through an available recovery system.

    - Paper bags can be recycled through widely available kerbside collection programs and are therefore the most recyclable. The kerbside recycling rate for paper and cardboard was estimated to be 65% in 2007 (Lewis 2008).

    - HDPE plastic bags can be recycled through supermarket collection bins, although this is less convenient than kerbside recycling programs. It has been estimated that 16% of bags were recycled in 2007 (Hyder Consulting 2008). If the recycling rate for HDPE bags increased from 16% (the baseline figure modelled in the LCA) to 50%, its greenhouse emissions would fall from 7.5 kg per year to 6.5 kg per year. This is the same as the emissions associated with a reusable PET bag, which has the second lowest impact for this category (the reusable PP bag has the lowest impact for greenhouse emissions).

    - Compostable bags can potentially be recovered through kerbside organic material collections or home composting systems, although there are a number of issues which need to be resolved before this can be done. First, the bags would need to be certified to the relevant Australian Standard or a similar international Standard for commercial and/or home composting[1]. Second, re-processors (composters) would need to be consulted to ensure that compostable bags are acceptable in their process, and whether there are any limits or special requirements. Finally, consumers would need to be educated about how to correctly dispose of the bags through their kerbside organic collection and/or home composting system. The last two strategies are an appropriate role for government in consultation with retailers and bag suppliers.

- If the recovery rate for compostable bags increased from 10% (the baseline assumed for the LCA) to 20 or 30%, its environmental impacts would reduce slightly but its relative ranking for impacts such as greenhouse emissions would not change.
- Oxo-degradable bags are not recoverable. Plastics recyclers are generally unwilling to accept them, because they can potentially reduce the quality of the recycled material. There is also no evidence that they are compostable.

The relative environmental impact of the different bags, based on the LCA analysis, is shown in **Table 1**. In this analysis the bag with the lowest impact (the best or environmentally preferred bag) has been given a score of ‘100’ and all other bags have been given a proportional score. The lowest impact bag for each of the impact categories is highlighted in green and the highest impact bag is highlighted in orange (if two or more bags have almost identical scores then they are all highlighted). For example, the preferred bag for global warming is the reusable ‘green bag’ (the highest ranking, highlighted in green) and the least preferred is the paper bag (the lowest ranking, highlighted in orange). For land use the preferred bag is the oxo-degradable bag, and both the paper bag and the compostable bag are highlighted as least preferred.

The issues for each type of bag at end of life are summarised in **Table 2**.

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[1] The Australian Standard for compostable polymers in commercial reprocessing facilities is AS 4736 - *Biodegradable plastics - biodegradable plastics suitable for composting and other microbial treatment.*

## Table 1: Relative ranking of bag options

| Impact category | HDPE Plastic bag 100% virgin | HDPE plastic bag with recycled content | Compostable bag | Oxo degradable bag | Paper bag | Reusable PET bag | Reusable PP green bag |
|---|---|---|---|---|---|---|---|
| **Global Warming** | 72.1 | 73.8 | 59.1 | 81.1 | 12.1 | 83.9 | 100.0 |
| **Photochemical oxidation** | 8.2 | 9.7 | n/a# | 10.2 | 5.1 | 72.8 | 100.0 |
| **Eutrophication** | 60.5 | 63.4 | 1.1 | 75.0 | 8.9 | 85.5 | 100.0 |
| **Land use** | 13.8 | 15.4 | 0.3 | 100.0 | 0.0 | 45.1 | 69.4 |
| **Water Use** | 92.4 | 23.1 | 24.6 | 100.0 | 2.9 | 32.0 | 77.6 |
| **Solid waste** | 29.5 | 24.4 | 96.9 | 31.4 | 24.9 | 100.0 | 24.5 |
| **Fossil fuels** | 32.4 | 33.9 | 64.9 | 36.0 | 14.4 | 100.0 | 97.3 |
| **Minerals** | 3.0 | 3.2 | 0.2 | 1.4 | 0.3 | 73.7 | 100.0 |

**Notes:** ‘100’ equals the best option from an environmental perspective. #Calculation not valid due to inability to calculate the compostable option in software.

🟩 Lowest impact

🟧 Highest impact

## Table 2: Advantages and disadvantages of shopping bags at end of life

| Bag option | Reuse | Recycling | Home composting | Commercial composting | Litter | Landfill |
|---|---|---|---|---|---|---|
| Single-use HDPE bag | Approx. 60% are reused in the home, e.g. as bin liners. | Recyclable through collection points in supermarkets but the recovery rate is low (approx. 16%). | Not compostable. | Not compostable. | Approx. 30-40 million bags (1%) become litter. They have a relatively high impact due to their visibility and potential hazard to wildlife. | Minimal impact as they are non-degradable. |
| Single-use compostable bag | Like HDPE bags, these are likely to be reused around the home for bin liners etc. | Non-recyclable, and may contaminate existing collection programs for HDPE bags. | It is not clear whether all compostable bags certified to AS 4736 are suitable for home composting systems. An Australian Standard is being developed. | Bags certified to AS 4736 can be recovered in a commercial composting facility but most Councils do not allow consumers to add other materials to an organics collection. | May break down faster than HDPE bags in litter, but only if exposed to necessary triggers (water, heat, bacteria). | May start to break down in landfill but degradation is unlikely to be complete. Degradation will generate $CO_2$ and methane. |
| Single-use oxo-degradable bag | Like HDPE bags, these are likely to be reused around the home for bin liners etc. | Non-recyclable, and may contaminate existing collection programs for HDPE bags. | Not compostable. | Not compostable. | May break down faster than HDPE bags, but only if exposed to the necessary triggers (heat, light, mechanical stress). Ecological impacts of the prodegradant additive are unknown. | There is no advantage in landfill compared to HDPE bags. |
| Single-use paper bag | Potential for reuse is limited. | Recyclable through kerbside collection programs. | Compostable if shredded and added to an effective home composting system. | Can be recovered in a commercial composting facility but most Councils do not allow consumers to add other materials to an organics collection. | Low impact in litter because they break down quickly and are not dispersed as easily as plastic bags. | May start to break down in landfill but degradation is unlikely to be complete. Degradation will generate $CO_2$ and methane. |
| Reusable PP or PET bag | Can be reused repeatedly – approx. 104 times (weekly for 2 years). | Can be recycled at the end of their life (once damaged) through supermarkets. | Not compostable. | Not compostable. | Unlikely to enter the litter stream. | Minimal impact as they are non-degradable. |

# Introduction and methodology

This report evaluates the environmental impacts of supermarket shopping bags used in Australia. It was developed by:

- Undertaking a streamlined LCA study of 7 shopping bags which updated previous studies (see Table 3 for full details)[2];
- Reporting the environmental impacts from the LCA review and modelling by:
  - tabulating the data in absolute units as well as an 'equivalency format' to make the data easier to understand, for example 10 litre buckets for water usage,
  - graphically representing the relativity of impacts for the 7 bag options on a normalised scale and,
  - ranking the bag options for each impact category, with the highest ranking bag given a score of '100' and all other bags given a relative score[3]; and
- Conducting a sensitivity analysis for some of the key assumptions used for the LCA, i.e. the composting rates for compostable bags, the recycling rate for HDPE bags, the recycling rate for reusable PP bags, the number of times the reusable PP and PET bags are reused and the number of times paper bags are used; and
- Reviewing the end of life disposal practices, advantages and limitations for the 7 shopping bag options.

Full details of the assumptions made in performing the review and further modelling are included in Table 3 and Table 4.

The LCA updated several studies undertaken by Karli James and Tim Grant at RMIT University (Nolan-ITU, 2002; ExcelPlas, 2003; James and Grant, 2005). These updates have included reassessment of bag weights, updates in background electricity and energy models across the entire life cycle, inclusion of fibre production for the PET and PP reusable bags and increases in the recycling rate of HDPE bags. Transport of bags or bag materials from overseas has been excluded as this information could not be obtained.

The LCA was undertaken using the SimaPro® software. To allow the different bags (single use and reusable) to be compared, the analysis was based on a common 'functional unit', defined as **the number of shopping bags consumed by a household to carry 70-grocery items home from the supermarket each week for 52 weeks**. The system that was modelled (Figure 1) included the growing and processing of the corn-starch material, material extraction and production of the polymers, growing trees and manufacturing pulp for paper, manufacture of bags from each of the raw materials, transport, use and waste management of the product. The production of PET and PP fibres was also included. Post-consumer waste management options included in the model were, recycling and commercial composting for the applicable materials and the reuse of bags as bin liners (only applicable for single use polymer bags).

A qualitative analysis was also undertaken for end of life recovery options. Certain assumptions are built into the LCA model (e.g. a 16% recycling rate for HDPE bags) but issues associated with

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[2] The study is referred to as a 'streamlined LCA' because it used existing data in SimaPro software rather than data from the actual processes used for each specific bag. The results therefore represent indicative environmental impacts rather than a full scientific study.

[3] A simple ranking of 1 – 5 could have been used (this was the approach taken in the Hyder (2008) report). However, this would have been misleading, as the differences between bags are sometimes small and insignificant. A ranking from 1 – 100 provides a more accurate picture of the relative impact of the bags for each impact category.

recycling, biodegradation and litter are complex and require more analysis. The disposal and recovery options for the different bags vary and are dependent upon at least three factors:

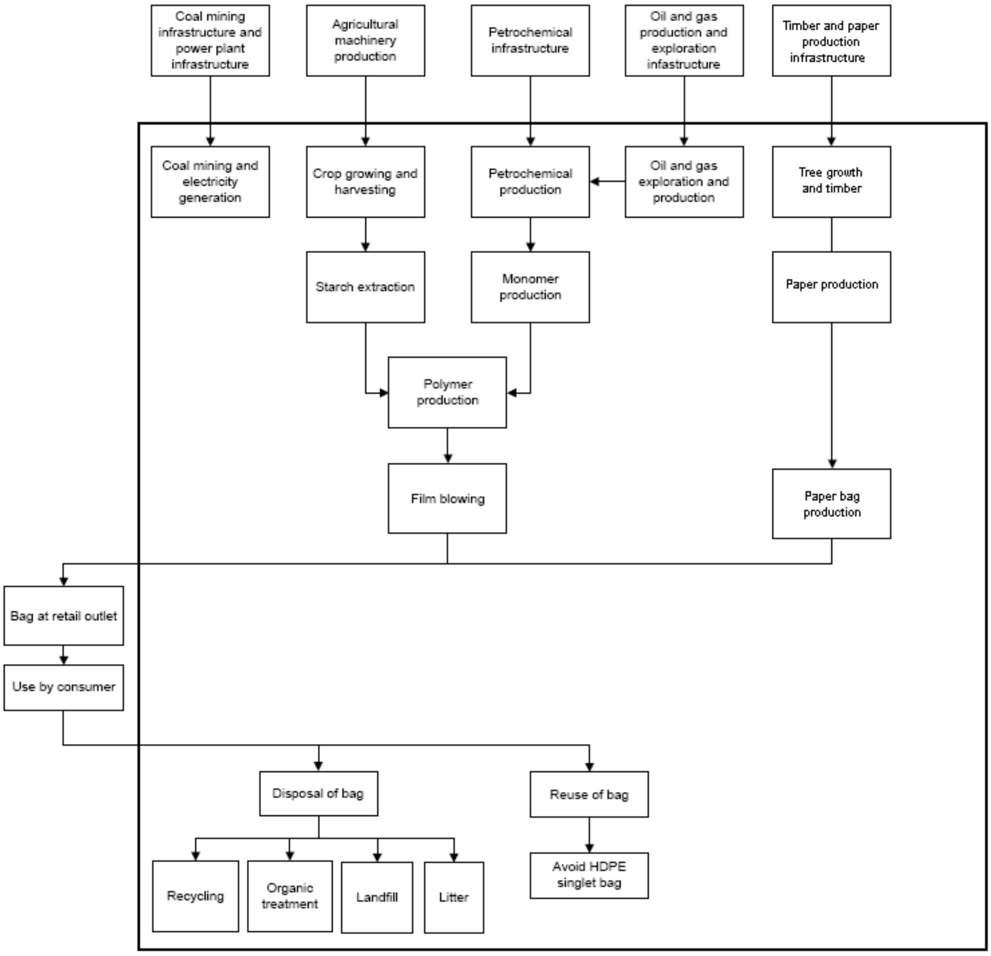
- the design of the bag, including the primary material used and its durability;
- the available infrastructure for collection and recovery of this type of bag; and
- the behaviour of individual consumers.

The *potential* disposal and recovery routes for shopping bags are presented in **Figure 2**. The review of issues relating to the end of life disposal was used to inform the assumptions for the updating and interpreting the life cycle impacts.

Eight environmental indicators were assessed for each shopping bag option, and these are defined in **Table 9** and

**Table 10** in Appendix 1. Litter was excluded from the LCA analysis because there is no reliable data available on the average length of time taken for each of the bag materials to degrade or their ecological impact in the natural environment (these issues are considered in the qualitative analysis in section 9).

**Figure 1: System boundary for the study**



**Note:** All processes within the box (system boundary) have been included in the study.

## Table 3: Details and assumptions of bags assessed

| Bag Type | Bag Material Composition | Relative capacity[(1)] | Expected life (trip rate) | Bags per year[(2)] | Bag volume | Assumptions made[(3)] |
|---|---|---|---|---|---|---|
| Single use high density polyethylene (HDPE) | HDPE (96.5%), White masterbatch (3.5%)<br>Total mass: 7.7g | 1 | Single trip | 520 | 360 x 300 x 200 = 0.0216m$^3$ | • HDPE material production. |
| Single use HDPE with recycled material | HDPE (81.5%), Recycled HDPE (15%), White masterbatch (3.5%)<br>Total mass: 7.7g | 1 | Single trip | 520 | 360 x 300 x 200 = 0.0216m$^3$ | • HDPE material production. |
| Single use compostable bag as per European or Australian standards | 50% starch from maize, 50% polycaprolactone (PCL)<br>Total mass: 8.1g | 1 | Single trip | 520 | 485 x 400 x 65 = 0.01261m$^3$ | • Maize growing based upon data related to growing maize in the Netherlands.<br>• PCL is produced from cyclohexanone (95%) and acetic acid (5%). |
| Single use oxo-degradable plastic bag | HDPE (97%), Prodegradant additive (3%)<br>Total mass: 6.0g | 1 | Single trip | 520 | 370 x 300 x 140 = 0.0155m$^3$ | • Additive modelled as stearic acid & small amount of cobalt metal to represent the presence of cobalt stearate. |
| Single use paper bag | Brown kraft 95.gsm (90%), Brown kraft 65.gsm (2%), Brown kraft 80.gsm (5%)<br>Total mass: 47g | 0.9 | Single trip (a) | 520 | 340 x 320 x 145 = 0.0158m$^3$ | • Production of paper. |
| Reusable 100% recycled PET bags | PET (4) (100%)<br>Total mass: 50g | 1.1 | 104 trips (2 years) (b) | 4.1 | 410 x 390 x 95 = 0.0152m$^3$ | • Recycled polyethylene terephthalate.<br>• Fibre production included. |
| Reusable polypropylene (PP) green bag | PP (57%), Nylon (43%)<br>Total mass: 115.9g | 1.1 | 104 trips (2 years) (b) | 4.1 | 300 x 300 x 230 = 0.0207m$^3$ | • Polypropylene production.<br>• Fibre production included. |

**Notes:**
(1) A relative capacity of 1 = 6-8 items per bag. For the purposes of this study, 7 items to a bag for a relative capacity of one was used.
(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.
(3) Ink, thread and adhesives not modelled for bag options. Life cycle inventory data sourced from Australian LCA database used in SimaPro 7.1 at the Centre for Design, RMIT University. Transport of bags or material was not included as particular source of material was not obtained.
(4) To avoid double counting we have accounted for recycling at end of life instead of giving credits at front of life.
(a) Sensitivity analysis of the paper bag – single trip baseline, two trips sensitivity – see sensitivity section for results.
(b) Sensitivity analysis of the PP reusable bag – 104 trips baseline, 52 trips sensitivity, one trip sensitivity – see sensitivity section for results.

## Table 4: End of life waste management modelling assumptions (baseline)

| **Bag type** | **Percentage (%)** | | | | |
|---|---|---|---|---|---|
| | **Recycled** | **Composted** | **Littered** | **Landfilled** | **Reused as a bin liner for household waste and then landfilled**(f) |
| Single use high density polyethylene (HDPE) | 16 (1) (c) | 0 | 0.5 | 64.5 | 19 |
| Single use HDPE with recycled material | 16 (1) | 0 | 0.5 | 64.5 | 19 |
| Single use compostable bag as per European or Australian standards | 0 | 10 (d) | 0.5 | 70.5 | 19 |
| Single use oxo-degradable plastic bag | 0 | 0 | 0.5 | 80.5 | 19 |
| Single use paper bag | 60 | 0 | 0.5 | 39.5 | 0 |
| Reusable 100% recycled PET bags | 0 | 0 | 0.1 | 99.9 | 0 |
| Reusable polypropylene (PP) green bag | 0 (e) | 0 | 0.1 | 99.9 | 0 |

**Source:** Adapted from James and Grant (2005)

**Notes:**

(1) According to EPHC (2008) the number of HDPE bags recycled in 2007 was 16% (calculated based on Figure 1, page 5 in (EPHC, 2008) – 3.93 billion bags consumed and 610 million recycled).

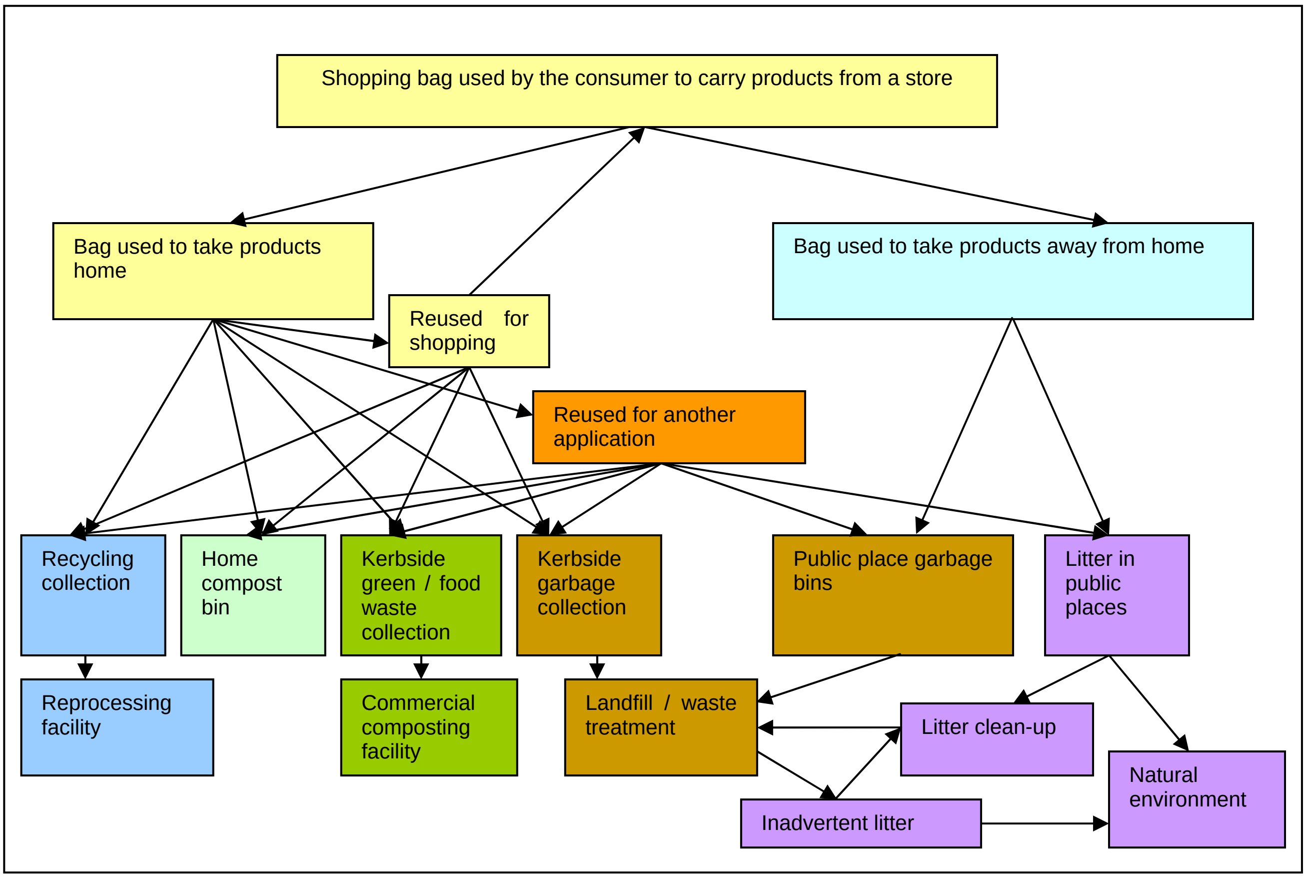
(c) Sensitivity recycled rate HDPE – 16% recycling baseline, 30% and 50% sensitivities – see sensitivity section for results.

(d) Sensitivity compostable bag – 10% composting baseline, 20% and 30% sensitivities – see sensitivity section for results.

(e) Sensitivity recycling rate for reusable bags – 0% baseline, 10% sensitivity – see sensitivity section for results.

(f) The LCA includes the avoided environmental impacts of bin liners.

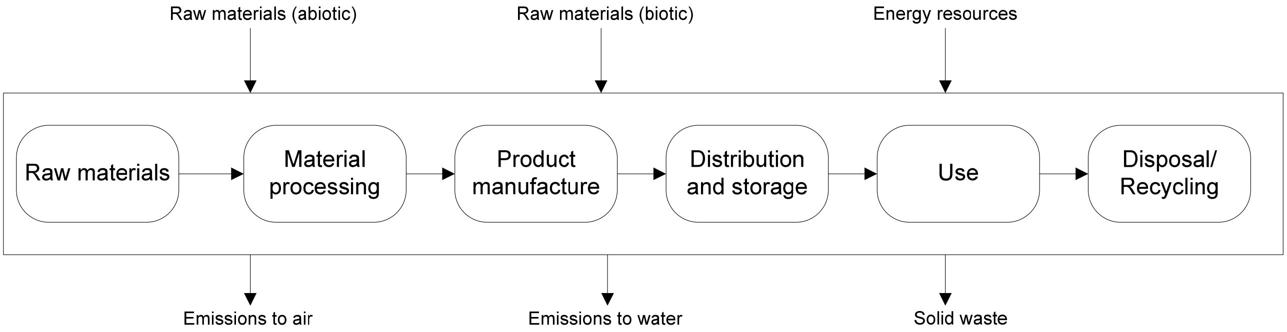
**Figure 2: Potential disposal and recovery options for shopping bags**



## Life Cycle Assessment (LCA) approach

Life cycle assessment (LCA) is the process of evaluating the potential effects that a product, process or service has on the environment over the entire period of its life cycle. Figure 3 illustrates the life cycle system concept of natural resources and energy entering the system with products, waste and emissions leaving the system.

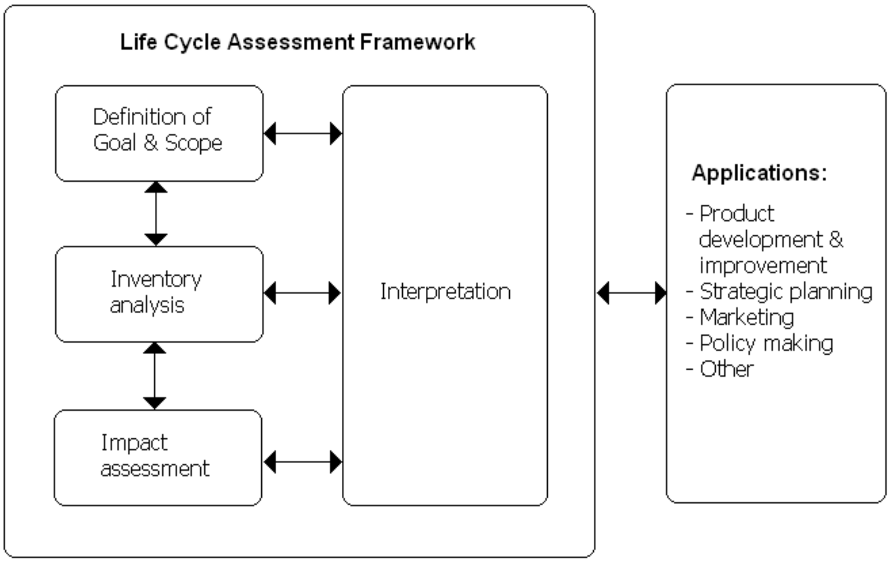
**Figure 3: Life cycle system concept**



The International Standards Organisation (ISO) has defined LCA as: '[A] Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its lifecycle' (ISO, 2006, p. 2).

The technical framework for LCA consists of four components, each having a very important role in the assessment. They are interrelated throughout the entire assessment and in accordance with the current terminology of the International Standards Organisation (ISO). The components are goal and scope definition, inventory analysis, impact assessment and interpretation as illustrated in Figure 4.

**Figure 4: The framework for LCA**



**Source:** ISO (2006, p. 8)

Goal and scope definition: At the commencement of an LCA, the goal and scope of the study needs to be clearly defined. The goal should state unambiguously the intended application/purpose of the study, the audience for which the results are intended, the product or function that is to be studied, and the scope of the study. When defining the scope, consideration of the reference unit, system boundaries and data quality requirements are some of the issues to be covered.

Inventory analysis: Inventory analysis is concerned with the collection, analysis and validation of data that quantifies the appropriate inputs and outputs of a product system. The results include a process flow chart and a list of all emissions and raw material & energy inputs (inventory table) that are associated with the product under study.

Impact assessment: The primary aim of an impact assessment is to identify and establish a link between the product's life cycle and the potential environmental impacts associated with it. The impact assessment stage consists of three phases that are intended to evaluate the significance of the potential environmental effects associated with the product system:

- The first phase is the characterisation of the results, assigning the elemental flows to impact categories, and calculating their contribution to that impact.
- The second phase is the comparison of the impact results to total national impact levels and is called normalisation.
- The third phase is the weighting of these normalised results together to enable the calculation of a single indictor result. In this study, only the first two phases are undertaken.

Interpretation: Interpretation is a systematic evaluation of the outcomes of the life cycle inventory analysis and/or impact assessment, in relation to the goal and scope. This interpretation provides the conclusions of the environmental profile of the product or system under investigation, and recommendations on how to improve it.

## Shopping bag materials, usage & disposal

### *Single use HDPE bags*

*Consumption and reuse*

Approximately 3.9 billion single-use HDPE shopping bags were consumed in Australia in 2007[4]. Many of these are reused by consumers for shopping and alternative uses, such as bin liners and food storage. In 2003, 86% of Australians said that they recycle or reuse plastic bags, and of this group, 10% took them to a central collection point other than a waste transfer centre and 88% reuse them within the home (ABS, 2003). It has been estimated that around 2.4 billion shopping bags (60%) are reused before being recycled or disposed to landfill (EPHC, 2008, p. 5).

*Recycling*

National collection and recycling programs for plastic shopping bags have been established by the two major supermarket chains, Coles and Woolworths, and Metcash recycles bags from its larger metropolitan supermarkets. According to Coles Group (2007), their collected bags are recycled into flower pots, irrigation pipe and garbage bins. There is also some ‘closed loop’ recycling back into shopping bags. However, recovery rates are still relatively low. Approximately 610 million bags were recycled in 2007 (EPHC, 2008, p. 5) which is equivalent to a recycling rate of around 16%.

*Landfill*

Most of the bags that are not recycled end up in landfill, where they do not degrade. This is not necessarily an environmental problem, because most landfills are designed to minimise degradation by compressing waste and removing leachate. Plastic bags make up a very small proportion of waste to landfill[5].

*Litter*

Approximately 40 million single-use plastic bags are littered each year, and only 5-10 million of these are collected through litter clean-up programs (EPHC, 2008, p. 5). Plastic bags make up less than 1% of all littered items (KAB, 2008, p. 63)[6] but are highly visible and persistent in the environment. They also pose a potential hazard to wildlife if ingested. A plastic bag will start to break down in the natural environment if exposed to ultraviolet light, but in the short term this can add to the litter problem if the bag breaks down into a larger number of smaller fragments. The rate of degradation is likely to depend on climate, the thickness of the bag and where it ends up (for example in soil, fresh or marine water, or snagged on trees or fences).

### *Single use compostable plastic bags*

*Consumption*

‘Compostable plastics’ are those that biodegrade through the action of microorganisms under composting conditions.

A large number of polymers labelled ‘biodegradable’, ‘compostable’ or ‘degradable’ have been introduced into Australia in recent years, and some of these are being used to manufacture

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[4] Hyder (2008, p. 1) have estimated that the total number of single-use HDPE shopping bags consumed in Australian in 2007 was 3.9 billion, and that approximately 10% of these were oxo-degradable HDPE bags. This means that non-degradable bag consumption is approximately 3.5 billion.

[5] Plastics as a whole make up around 4% of municipal waste in landfill (Productivity Commission, 2006, p. 19).

[6] According to the national Keep Australia Beautiful survey in May 2008, light weight HDPE checkout bags were 0.6% of all littered items (KAB, 2008, p. 63).

shopping bags. This has caused some confusion amongst consumers and businesses about the meaning and accuracy of claims. Standards Australia responded by initiating the development of a series of standards to control their use. The first of these (AS 4736-2006) is intended to regulate the labelling of plastics as ‘compostable’[7]. This Standard describes the specific requirements that a polymer needs to meet to ensure that it ‘biodegrades’ and that the break-down products and the speed of degradation are compatible with a commercial composting process[8].

The consumption of compostable plastic shopping bags in 2007 was limited to retailers of ‘environmentally responsible’ products such as organic food stores (Hyder Consulting, 2008). However, consumption is expected to increase from May 2009 with the introduction in South Australia of a ban on non-compostable single-use plastic shopping bags[9]. A common example of a compostable plastic used to make bags in Australia is Mater-Bi®, which is manufactured from corn starch, but there are many others available on the market[10].

One of the concerns expressed about compostable polymers manufactured from crops such as corn (‘biopolymers’) is that they may be adding pressure to the supply and cost of food crops. However, they have the potential to reduce the amount of waste generated by shopping bags in two ways:

- by diverting shopping bags from landfill into a commercial composting facility or a home compost bin; and
- by facilitating the degradation of shopping bags in the natural environment, thus minimising their visual impact and potential hazard to wildlife.

*Recovery*

The main avenue for the collection of compostable plastic bags for commercial composting is the kerbside collection programs for green and/or food waste run by Local Councils. An increasing number of Councils are collecting green wastes at kerbside, and some are starting to collect food wastes in the same bin. This trend is expected to continue but it is unlikely, at least in the short to medium term that residents will be allowed to include biodegradable packaging. Councils advise residents about the types of material that can be included, and they generally don’t mention compostable paper or plastics. In Nillumbik Shire (Victoria), residents are specifically instructed NOT to include plastics or biodegradable plastics in their bin or it will be rejected by the processor (DEC, 2007). Some Councils in Australia have trialled the use of compostable ‘kitchen tidy’ bags for organics collections, but after the initial trial period have encouraged residents to wrap food waste in newspapers. In addition to the additional cost of compostable bags, there was concern that residents would start to use conventional plastics bags if they ran out of compostable bags

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[7] Standards are being developed for each of the primary end environments, i.e. commercial composting, home composting, marine water, freshwater and on soil. The performance standard for commercial composting has been completed: Australian Standard 4736-2006, *Biodegradable plastics—biodegradable plastics suitable for composting or other microbial treatment*. The first draft of the Standard for home composting is currently being finalised.

[8] A biodegradable polymer is capable of being broken down by microorganisms in the presence of oxygen (aerobic) to carbon dioxide, water, biomass and mineral salts or any other elements that are present (mineralisation), or capable of being broken down without the presence of oxygen (anaerobic) to carbon dioxide, methane, water and biomass. To be compatible with a commercial composting facility a product needs to degrade at least 90% by weight within a 12 week period, with minimal toxicity impacts (Standards Australia, 2006).

[9] From 1 May 2009 retailers will not be allowed to sell or give away plastic bags with handles, made of polyethylene polymer less than 35 microns thick. Compostable bags that are certified to Australian Standard AS4736 are exempt from the ban.

[10] For a list of polymers certified to AS 4736 and EN 13432, see http://www.pacia.org.au/deg_verprod_ls.pdf.

(DEC, 2007). Plastics are problematic in compost because they do not break down in the required time and reduce the quality of the end product.

In South Australia, where retailers are starting to sell compostable plastics bags at the checkout, consumers are being encouraged to compost their bags through Council-run green and food waste collections, if available[11], or to take their bags to an organics processing facility.

An alternative is to add compostable bags to home composting systems. Around one-third of Australians currently compost food waste at home[12], but not all compostable polymers are suitable for the low temperatures found in home composting facilities (WRAP, 2007). An Australian Standard for biodegradable plastics in home composting systems is currently being drafted.

Compostable bags are not recyclable, and are a potential contaminant if added to existing collection programs for HDPE bags because they will reduce the quality of the recycled product.

The appropriate disposal of compostable bags will need to be encouraged through effective education programs and labelling. This is a difficult message to convey, because even highly motivated recyclers are confused about the best option for recovery and may place them into a recycling or garbage bin (WRAP, 2007).

*Landfill*

The time taken for compostable plastics to break down in landfill is unknown (ExcelPlas, 2003). In a conventional ‘dry’ landfill, there is only likely to be limited degradation because the essential triggers—heat, water and bacteria—are not available once the waste material has been compressed. Archaeological studies in the United States have shown that even organic materials such as paper and food show very little degradation after being buried for decades (Rathje and Murphy, 1992). Aerobic degradation that occurs close to the surface of a landfill (in the presence of oxygen) generates carbon dioxide. At deeper levels of burial, landfills change from aerobic to anaerobic, so any degradation that does occur results in emissions of methane, a potent greenhouse gas. This is not a significant problem for landfills with effective recovery systems for methane and carbon dioxide.

Alternative waste treatment (AWT) facilities are starting to be established in Australia, and these have the potential to recover energy and biomass from compostable materials in the future. New technologies include ‘wet’ bioreactor landfills and integrated resource recovery facilities[13].

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[11] Zero Waste SA is currently funding a food waste collection trial in 10 Councils. Councils provide residents with a kitchen tidy bin and compostable bags, and ask residents to add these to their green waste bins. A compostable bag used by Target in Adelaide includes the following message: ‘This packaging is compostable only at organic recycling facilities used by Councils offering a kerbside green waste collection service. Unfortunately, not all Australian Councils offer this service. Please contact your Local Council for availability in your area. Alternatively you could take it yourself to an organics processor.’

[12] In 2003, 47% of people said that they recycled kitchen or food waste, and 69% of this group did so through compost or mulch (ABS, 2003).

[13] Unlike dry landfills, wet landfills actively encourage anaerobic degradation by re-circulating leachate (WMAA, 2008). Mixed resource recovery facilities, which recover recyclables, energy and organic materials, include Global Renewable U3-R3 facility at Eastern Creek (http://www.globalrenewables.com.au/ur3r-process/description) and the Macarthur Park Resource Recovery Centre, both in Sydney. When Macarthur Park is fully operational (expected to be March 2009), it will extract recyclable materials from household garbage, and food and garden waste will be processed to recover energy (from methane and carbon dioxide). The residual material from this process will be sold as compost. See http://www.wsn.com.au/dir138/wsn.nsf/Content/News_Macarthur+Resource+Recovery+Park+Opens.

*Litter*

It is not known how long compostable bags will take to break down in litter (ExcelPlas, 2003). They will only start to break down when they come into contact with the necessary triggers—heat, water and bacteria—and may therefore persist in the environment for some time. Australian Standards are yet to be developed for biodegradable polymers in litter environments, including on soil and in marine and fresh water.

### *Single use oxo-degradable plastic bags*

*Consumption*

'Oxo-degradable plastics' are made from a conventional polymer, such as polyethylene, and a small amount of a 'prodegradant' additive that can trigger and accelerate the degradation process. Oxo-degradable plastics break down when exposed to natural daylight, heat and/or mechanical stress (ExcelPlas, 2003).

Approximately 10% of bags consumed in high volume supermarkets in 2007 involved the use of oxo-degradable bags, and around 15% of bags consumed in other retail sectors (Hyder Consulting, 2008, p. 2). For example, Metcash uses oxo-degradable bags in rural areas where there is no pick-up facility available for recycling.

*Degradation process*

There is some evidence that degradation of these materials occurs through a two-stage process; first breaking down into small pieces when exposed to heat, ultraviolet light or mechanical stress and then biodegrading through the action of microorganisms (bacteria). However, this process can take an extended period of time, and there are unanswered questions about the completeness of biodegradation and the ecological impacts of the prodegradant additives (Bonhomme *et al.*, 2003; Chan *et al.*, 2003; Chiellini *et al.*, 2003; Jakubowitcz *et al.*, 2006).

Some shopping bags in Australia are made from an oxo-degradable plastic manufactured by EPI. The prodegradant used by EPI is cobalt stearate. Despite cobalt being considered a 'heavy metal', the very low levels in the composition of the bag mean that it is unlikely to pose a potential health risk to humans or any natural eco-system.

*Recovery*

There is no evidence available that oxo-degradable shopping bags are compatible with commercial or home composting systems. One study found that oxo-degradable film breaks down at a slower rate in composting conditions than in air (Jakubowitcz *et al.*, 2006).

Oxo-degradable bags are a potential contaminant if added to existing recycling programs for HDPE bags. In the absence of any evidence supporting the compatibility of oxo-degradable bags in composting or recycling systems, the best option for disposal is landfill.

*Landfill*

Some bags include the claim '100% degradable in landfills', but there is no evidence to support this.

*Litter*

There is very little data available on the impacts of oxo-degradable bags in the natural environment. Oxo-degradable shopping bags may break down at a faster rate in the litter stream than conventional plastic bags, but the degradation process is likely to take an extended period of time[14]. The Environment Protection and Heritage Council (EPHC) is currently funding research on

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[14] For example, one study found that oxo-degradable samples that were irradiated for 14 days degraded to about 50% after 180 days of biodegradation and continued to biodegrade after this period (Chan *et al.*,

the degradation of a range of plastics, including oxo-degradable plastics, to inform the development of Australian Standards.

## Single use paper bags

### *Recovery*

Paper bags are recyclable through kerbside collection programs. The recycling rate for post-consumer paper in Australia reached 65% in 2007 (Lewis, 2008). Paper bags are also compostable, which means that they can be added to home composting systems. They need to be shredded first to facilitate degradation. Most Councils with a green / food waste collection program do not encourage householders to include paper.

### *Landfill*

Paper degrades to a certain extent in landfill, and in the process generates carbon dioxide (in aerobic conditions) and methane (in anaerobic conditions). As already discussed, degradation of organic materials is limited in dry landfills due to the absence of water, heat and bacteria once the material has been buried and compressed. Most landfills have some gas recovery.

### *Litter*

Some paper shopping bags may also end up as litter, but the Keep Australia Beautiful data does not distinguish between different types of paper bags. Paper bags as a whole contributed 1% of littered items in the latest national survey (KAB, 2008, p.62). However, paper bags have less impact than plastic bags if they end up in the litter stream because will break down relatively quickly. Unlike plastic bags they are not easily dispersed by wind or water, and are unlikely to end up snagged on trees and fences. As a result their visual impact is less and there are no documented risks of damage to wildlife.

## Reusable PET and PP bags

### *Consumption*

In stores that do not charge for single-use bags, it has been estimated that 13% of transactions involve a designed-for-purpose reusable bag (Hyder Consulting, 2008). In stores that charge a fee for single-use bags, the percentage increases to around 33%. It is often argued that the introduction of reusable bags will result in an increase in the number of ‘kitchen tidy’ bags purchased by consumers. However, analysis of trends between 2004 and 2006 found that the reduction in use of shopping bags far outweighed the increased sales of kitchen tidy bags (Hyder Consulting, 2008, p. 3)[15].

### *Recovery*

According to the South Australian Government, the reusable PP ‘green bag’ is recycled into long lasting plastic items such as park benches, playground furniture and bollards[16]. They can be recycled through the shopping bag collection bins at supermarkets, but according to Hyder (2007) this option is not widely promoted to consumers and very few are collected. There is also potential to recycle the PET bags through supermarket collection programs if sufficient volume can be obtained to make recycling viable.

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2003). In other research a biodegradation rate of around 60% was achieved after 18 months (Chiellini *et al.*, 2003).

[15] For example, the number of single-use plastic shopping bags consumed in 2006 fell by 560 million compared to the previous year, but the number of kitchen tidy bags only increased by 38 million (Hyder Consulting, 2008, p. 3).

[16] http://byobags.com.au/About.mvc/FAQ/102, accessed 16 February 2009.

## Shopping bag Life Cycle Assessment studies

There are several LCA studies that have been performed on alternative shopping bag materials in Australia (**Table 5**).

A streamlined LCA of alternative shopping bags was conducted by the Centre for Design at RMIT ('RMIT') in 2002 as part of a broader study of plastic shopping bags for Environment Australia (Nolan-ITU, 2002)[17]. The study was conducted in association with Nolan-ITU (now Hyder Consulting) and compared the environmental impacts of 10 alternative shopping bags (**Table 5**).

The study concluded that paper bags use the most material, followed by low density polyethylene (LDPE) 'boutique' bags. The most efficient containers in terms of material consumption were the three reusable plastic bags and the reusable plastic box. The highest impacts in terms of greenhouse emissions and energy use were the LDPE boutique bag, followed by the paper bag and then the single use biodegradable and HDPE bags. Litter impacts were highest for the LDPE boutique bag because of their higher weight and area compared to other single use bags.

This study was updated and extended by RMIT in research conducted for the Department of Environment and Heritage on degradable plastic bags (ExcelPlas, 2003) [18]. The environmental impact categories were changed slightly, for example, litter indicators were modified[19]. The number of degradable plastic bags that were modelled increased from one to six. The highest impact degradable bag, based on greenhouse gas emissions and eutrophication impacts, was the polylactic acid (PLA) bag, followed by the starch blend. The lowest impact bag for these indicators was the oxo-degradable bag. When degradable bags were compared to non-degradable bags in terms of greenhouse impact, the paper bag had the highest impact and the reusable bags had the lowest impact. Similar results were achieved for eutrophication. The HDPE bag had the highest impact for the two litter impacts and reusable bags had the lowest impact.

The LCA modelling that was used for the previous two studies was later updated by Hyder Consulting in a report to Sustainability Victoria (Hyder Consulting, 2007). The aim of this report was to help retailers and consumers to understand the environmental impacts of alternatives to the HDPE bag. The LCA results were presented in a less technical form, i.e. as a rating of one to five for each indicator instead of raw data from the SimaPro model. Some of the main conclusions from the report were:

- reusable bags have lower environmental impacts than all of the single use bags;
- a shift to more durable bags would deliver environmental benefits through reductions in greenhouse gases, energy and water use, resource depletion and litter;
- the re-usable, non-woven PP 'green bag' has the greatest environmental benefits'
- the change from one single use bag to another single use bag may improve one environmental outcome but the benefit may be offset by another environmental impact;
- recycled content generally reduces the overall environmental impact of bags; and
- the end of life destination is critical, with greater environmental savings achieved from recycling all bags at the end of their life.

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[17] Environment Australia is now the Department of Environment, Water, Heritage and the Arts (DEWHA).

[18] The Department of Environment and Heritage is now the Department of Environment, Water, Heritage and the Arts (DEWHA).

[19] The 'litter marine diversity' indicator was based on whether the plastic floats or sinks, how long it would float and how long it would take to sink. The 'litter aesthetic' indicator was based on the area of the bag and how long it would take to break down.

The environmental benefits of a household switching from single use HDPE bags to reusable ‘green bags’ was estimated to be:

- the equivalent of not releasing over 100 ‘black balloons’ of greenhouse pollution into the atmosphere;
- in terms of energy, the equivalent of powering a television for six months; and
- in terms of water, the equivalent amount of water used to flush the toilet (Hyder Consulting, 2007).

**Table 5: Comparison of streamlined LCA studies of alternative shopping bags**

| | **Nolan-ITU, RMIT and Eunomia (2002)** | **ExcelPlas, RMIT and Nolan-ITU (2003)** | **Hyder Consulting (2007)** |
|---|---|---|---|
| *Types of bags assessed* | Single use HDPE ‘singlet’ bag | Single use HDPE ‘singlet’ bag | Single use HDPE ‘singlet’ bag |
| | Single use HDPE ‘singlet’ bag with 50% recycled content | Single use paper bag | Single use HDPE ‘singlet’ bag with 100% recycled content |
| | Single use LDPE ‘boutique’ bag | Single use biodegradable starch blend | Single use LDPE ‘boutique’ bag |
| | Single use paper bag | Single use biodegradable PBS/A | Single use paper bag |
| | Single use biodegradable plastic bag | Single use biodegradable PBAT | Single use paper bag with 100% recycled content |
| | Reusable LDPE bag | Single use biodegradable starch polyester | Reusable paper bag (2 trips) |
| | Reusable calico bag | Single use oxo-degradable bag from HDPE and prodegradant | Reusable paper bag (2 trips) with 100% recycled content |
| | Reusable HDPE ‘swag bag’ | Single use biodegradable PLA bag | Single use oxo-degradable bag from HDPE |
| | Reusable PP ‘green bag’ | Reusable calico bag | Single use biodegradable starch blend |
| | Reusable PP ‘smart box’ | Reusable HDPE ‘swag bag’ | Reusable calico bag |
| | | Reusable PP ‘green bag’ | Reusable PP ‘green bag’ |
| *Environmental impact categories assessed* | Material consumption | Resource depletion | Material consumption |
| | Litter (weight, area, persistence (grams per year)) | Greenhouse emissions | Global warming |
| | Greenhouse emissions | Eutrophication | Energy consumption |
| | Energy use | Litter (marine diversity, litter aesthetics | Water use |
| | | | Litter (marine diversity, litter aesthetics) |

A study has also been conducted on the 'litterability' of single use plastic shopping bags for the Department of Environment and Heritage (Verghese *et al.*, 2006; Verghese *et al.*, 2008). The overall conclusion was that plastic bag design characteristics such as weight, material type, bag size, and wall thickness have a significant effect on the bag's mechanical properties, litterability and life cycle environmental impact (Verghese *et al.*, 2006; Verghese *et al.*, 2008). The study included a streamlined LCA of 13 different plastic bags, including various single use HDPE bags, single use linear low density bags (LLDPE) bags, compostable plastic bags and oxo-degradable bags. HDPE bags are stiffer and stronger and less stretchy than LLDPE bags. They also have lower greenhouse emissions and embodied energy than LLDPE bags as they are thinner and lighter. The effect of design characteristics on litterability is limited. All bags are prone to being caught by the wind and then being dispersed for long distances, until they are snagged. All bags are prone to being caught in water and dispersed for long distances (either on or below the surface) until they are snagged. Thin-gauged lightweight HDPE bags snag more easily than thick heavy bags in the wind (Verghese *et al.*, 2006; Verghese *et al.*, 2008).

## Shopping bag environmental impacts

### *Life cycle impacts*

**Table 6** presents the baseline data for the 8 environmental impact indicators for each bag for the same functional unit (i.e. the number of bags per year for 70 grocery items per week per household).

To provide a visual comparison of the differences between the shopping bags the data has been represented in **Figure 5** on a relative basis where the bag option with the highest impact on a particular impact measure is reported at 100%.

Finally, **Table 7** provides a relative ranking of the bags for each impact category. The number ‘100’ is given to the preferred option (i.e. the bag with the lowest impact) and each of the remaining options has been given a number representing its relative impact compared to the best option. For example, for global warming the reusable PP bag has the lowest impact and the paper bag has the highest impact.

Generally, the reusable bags (PET and PP) have lower environmental impacts than the single use bags. These findings are consistent with previous studies and illustrate the benefits that can be achieved when reusing an item for the same application. Overall the single use paper bag has the highest environmental impact as a result of pulp and paper production and the weight of material required per bag.

The life cycle processes and factors that are contributing to the environmental impacts are:

- *Global warming*: Driven by material resource consumption and energy use across the life cycle. The heavier the bag the more resources that are required, which has a flow on effect to material extraction processes and energy consumption. The reusable bags score the lowest impact as there are only 4 bags assumed to be used per year by a household with a total bag material consumption of 200 grams (PET bag) and 460 grams (PP bag) compared with 4 kg (HDPE bag) and 24.4 kg (paper bag). The greatest impact on this measure is for the paper bag, with an impact 8 times that of the lowest impact bag (reusable PP bag).
- *Photochemical oxidation*: Driven by volatile organic compounds generated across the life cycle for materials.
- *Eutrophication*: Linked to the release of nutrients into waterways. Raw materials sourced from land based operations (e.g., starch for compostable materials and fibre for paper) will have higher impacts in this impact indicator. The compostable bag has the greatest impact which is approximately 70 times greater than other bag options; with the exception of the paper bag (the compostable bag is approximately 7 times greater).
- *Land use*: Linked to the use of land for growing of crops and timber. Raw materials sourced from land based operations (e.g., starch for compostable materials and fibre for paper) will have higher impacts in this impact indicator. The paper bag has the greatest impact on this measure, significantly larger than all other bag materials.
- *Water use*: Driven by water consumption in material production. Greater volumes of water are consumed in pulp and paper production than for any of the other materials, hence the paper bag option shows the greatest impact on this measure.
- *Solid waste*: Includes solid waste generated during processes throughout the life cycle of each material as well as the waste generated by bags disposed to landfill. Solid waste impacts are lowest for the compostable bag and PET reusable bag and similar for most other bag options.

- *Fossil fuels*: Driven by the fossil fuels consumed as either raw materials or energy across the life cycle. The paper bag option has the greatest impact while the reusable bags are lower than other options.
- *Minerals*: Minerals that are consumed as raw material inputs across the life cycle. The paper bag has the greatest impact while the reusable bags are lower than other options.

### *End of life disposal*

The end of life disposal options and issues for the shopping bag options are summarised in **Table 8**. Impacts vary depending on the bag's design, the available collection infrastructure and consumer behaviour. In summary:

- Paper bags have the lowest impact in litter. Single use HDPE bags and paper bags make up a small percentage of littered items (both less than 1% according to Keep Australia Beautiful (2008). However, HDPE bags tend to have a higher impact because they are more visible and take longer to break down in the environment. They can also potentially cause injury to animals and wildlife if ingested. Compostable and oxo-degradable plastic bags are likely to break down at a faster rate than conventional HDPE bags but there is limited data available on how long degradation would take in different environments (e.g. soil, marine water, fresh water). The environmental impact of the prodegradant additive in oxo-degradable bags, which is based on heavy metal compounds, is also unknown.
- All of the bags have potential to be recovered at end of life rather than disposed of to landfill. Whether or not they are *actually* recovered depends on 3 things: the material it is made from, the infrastructure available for collection and reprocessing, and the willingness of consumers to dispose of the bag through an available recovery system.
    - Paper bags can be recycled through widely available kerbside collection programs and are therefore the most recyclable. The kerbside recycling rate for paper and cardboard was 65% in 2007 (Lewis 2008).
    - HDPE plastic bags can be recycled through supermarket collection bins, although this is less convenient than kerbside recycling programs. It has been estimated that16% of bags were recycled in 2007 (Hyder 2008).
    - Compostable bags can potentially be recovered through kerbside organic material collections or home composting systems, although there are a number of issues which need to be resolved before this can be done. First, the bags would need to be certified to the relevant Australian Standard or a similar international Standard for commercial and/or home composting[20]. Second, re-processors (composters) would need to be consulted to ensure that compostable bags are acceptable in their process, and whether there are any limits or special requirements. Finally, consumers would need to be educated about how to correctly dispose of the bags through their kerbside organic collection and/or home composting system. The last two strategies are an appropriate role for government in consultation with retailers and bag suppliers.
    - Oxo-degradable bags are not recoverable. Plastics recyclers are generally unwilling to accept them, because they can potentially reduce the quality of the recycled material. There is also no evidence that they are compostable because they have not to date been certified to relevant Standards.

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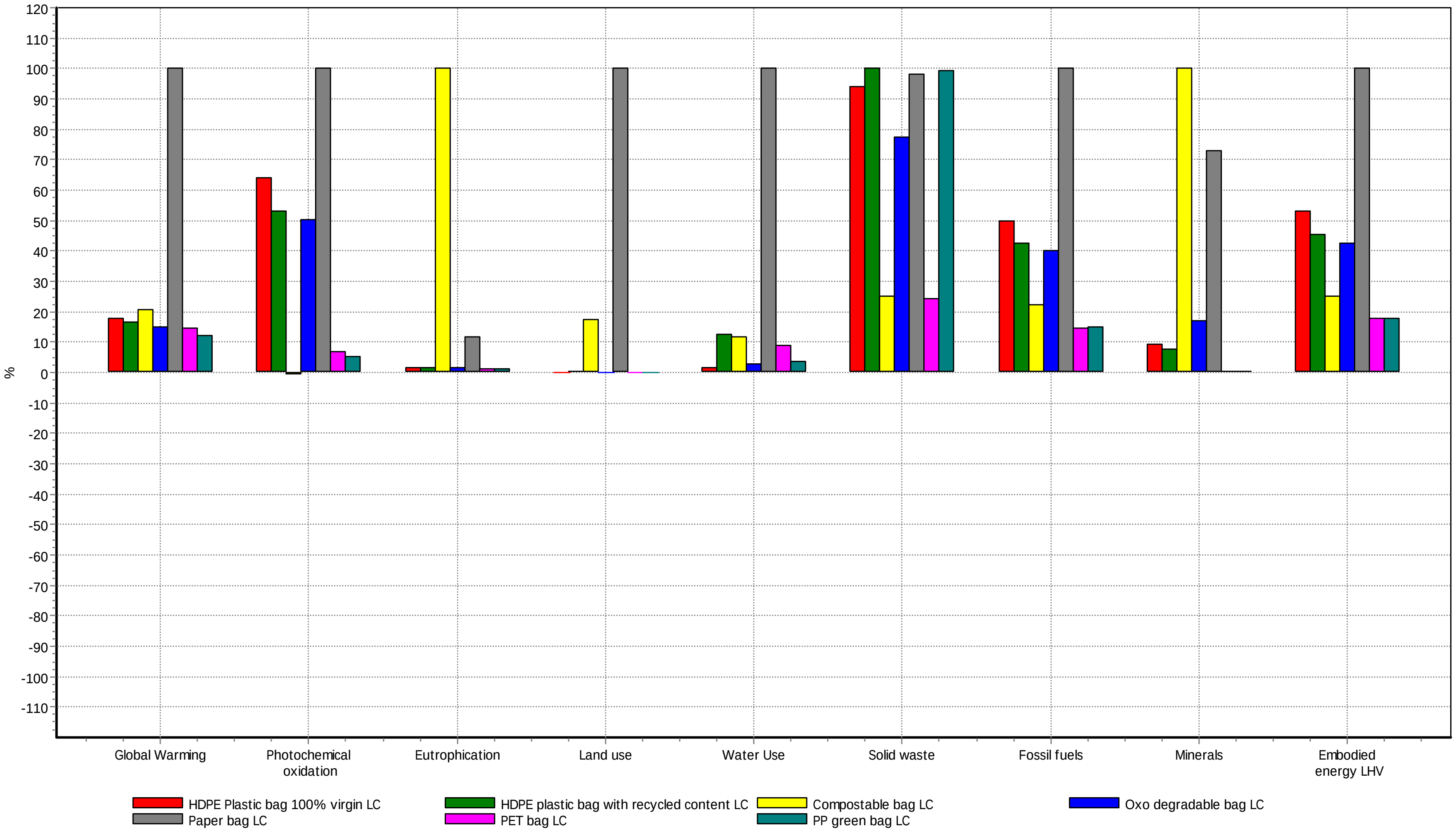
[20] The Australian Standard for compostable polymers in commercial reprocessing facilities is AS 4736 - *Biodegradable plastics - biodegradable plastics suitable for composting and other microbial treatment.*

### Table 6: Environmental impact indicators and equivalency units

| Impact category | Unit | HDPE Plastic bag 100% virgin | HDPE plastic bag with recycled content | Compostable bag | Oxo degradable bag | Paper bag | PET bag | PP green bag |
|---|---|---|---|---|---|---|---|---|
| Global Warming | *kg $CO_2$* | 7.52 | 7.35 | 9.19 | 6.69 | 44.74 | 6.47 | 5.43 |
| | *Bl. Balloons* | 150 | 147 | 184 | 134 | 895 | 129 | 109 |
| Photochemical oxidation | *kg $C_2H_4$* | 0.045 | 0.038 | -0.001 | 0.036 | 0.072 | 0.005 | 0.004 |
| | *m by car* | 56447 | 47959 | -658 | 45561 | 90439 | 6362 | 4632 |
| Eutrophication | *kg $PO_4^{---}$ eq* | 0.005 | 0.005 | 0.278 | 0.004 | 0.033 | 0.003 | 0.003 |
| | *L grey water* | 393 | 376 | 22343 | 317 | 2669 | 279 | 238 |
| Land use | *Ha a* | 6.627E-06 | 5.945E-06 | 3.489E-04 | 9.158E-07 | 1.992E-03 | 2.033E-06 | 1.320E-06 |
| | *footy fields* | 3.314E-06 | 2.972E-06 | 1.745E-04 | 4.579E-07 | 9.960E-04 | 1.016E-06 | 6.601E-07 |
| Water Use | *kL $H_2O$* | 0.013 | 0.053 | 0.050 | 0.012 | 0.423 | 0.038 | 0.016 |
| | *10L Buckets* | 1.322 | 5.286 | 4.955 | 1.221 | 42.259 | 3.814 | 1.572 |
| Solid waste | *kg* | 2.737 | 3.307 | 0.832 | 2.564 | 3.243 | 0.806 | 3.283 |
| | *240 L bins* | 0.005 | 0.006 | 0.001 | 0.005 | 0.006 | 0.001 | 0.006 |
| Fossil fuels | *MJ surplus* | 19.927 | 19.067 | 9.964 | 17.937 | 44.771 | 6.463 | 6.646 |
| | *Househ E*d* | 0.139 | 0.133 | 0.070 | 0.126 | 0.313 | 0.045 | 0.047 |
| Minerals | *MJ Surplus* | 8.445E-04 | 7.786E-04 | 1.018E-02 | 1.735E-03 | 7.423E-03 | 3.388E-05 | 2.497E-05 |
| | *Househ E*d* | 5.912E-06 | 5.450E-06 | 7.125E-05 | 1.215E-05 | 5.196E-05 | 2.372E-07 | 1.748E-07 |

## Figure 5: Relative environmental impact of bag options



Comparing product stages; Method: x Aus Imp Ass - DRAFT eq units (no carcin & ozone) V1.03 / characterization

**Table 7 Relative ranking of bag options**

| Impact category | HDPE Plastic bag 100% virgin | HDPE plastic bag with recycled content | Compostable bag | Oxo degradable bag | Paper bag | Reusable PET bag | Reusable PP green bag |
|---|---|---|---|---|---|---|---|
| **Global Warming** | 72.1 | 73.8 | 59.1 | 81.1 | 🟧 12.1 | 83.9 | 🟩 100.0 |
| **Photochemical oxidation** | 8.2 | 9.7 | n/a# | 10.2 | 🟧 5.1 | 72.8 | 🟩 100.0 |
| **Eutrophication** | 60.5 | 63.4 | 🟧 1.1 | 75.0 | 8.9 | 85.5 | 🟩 100.0 |
| **Land use** | 13.8 | 15.4 | 🟧 0.3 | 🟩 100.0 | 🟧 0.0 | 45.1 | 69.4 |
| **Water Use** | 92.4 | 23.1 | 24.6 | 🟩 100.0 | 🟧 2.9 | 32.0 | 77.6 |
| **Solid waste** | 29.5 | 🟧 24.4 | 96.9 | 31.4 | 🟧 24.9 | 🟩 100.0 | 🟧 24.5 |
| **Fossil fuels** | 32.4 | 33.9 | 64.9 | 36.0 | 🟧 14.4 | 🟩 100.0 | 97.3 |
| **Minerals** | 3.0 | 3.2 | 🟧 0.2 | 1.4 | 🟧 0.3 | 73.7 | 🟩 100.0 |
| **Notes:** '100' equals the best option from an environmental perspective. #Calculation not valid due to inability to calculate the compostable option in software. | | | | | | | |

🟩 Lowest impact

🟧 Highest impact

### Table 8: Advantages and disadvantages of shopping bags at end of life

| Bag option | Reuse | Recycling | Home composting | Commercial composting | Litter | Landfill |
|---|---|---|---|---|---|---|
| Single-use HDPE bag | Approx. 60% are reused in the home, e.g. as bin liners. | Recyclable through collection points in supermarkets but the recovery rate is low (approx. 16%). | Not compostable. | Not compostable. | Approx. 30-40 million bags (1%) become litter. They have a relatively high impact due to their visibility and potential hazard to wildlife. | Minimal impact as they are non-degradable. |
| Single-use compostable bag | Like HDPE bags, these are likely to be reused around the home for bin liners etc. | Non-recyclable, and may contaminate existing collection programs for HDPE bags. | It is not clear whether all compostable bags certified to AS 4736 are suitable for home composting systems. An Australian Standard is being developed. | Bags certified to AS 4736 can be recovered in a commercial composting facility but most Councils do not allow consumers to add other materials to an organics collection. | May break down faster than HDPE bags in litter, but only if exposed to necessary triggers (water, heat, bacteria). | May start to break down in landfill but degradation is unlikely to be complete. Degradation will generate $CO_2$ and methane. |
| Single-use oxo-degradable bag | Like HDPE bags, these are likely to be reused around the home for bin liners etc. | Non-recyclable, and may contaminate existing collection programs for HDPE bags. | Not compostable. | Not compostable. | May break down faster than HDPE bags, but only if exposed to the necessary triggers (heat, light, mechanical stress). Ecological impacts of the prodegradant additive are unknown. | There is no advantage in landfill compared to HDPE bags. |
| Single-use paper bag | Potential for reuse is limited. | Recyclable through kerbside collection programs. | Compostable if shredded and added to an effective home composting system. | Can be recovered in a commercial composting facility but most Councils do not allow consumers to add other materials to an organics collection. | Low impact in litter because they break down quickly and are not dispersed as easily as plastic bags. | May start to break down in landfill but degradation is unlikely to be complete. Degradation will generate $CO_2$ and methane. |
| Reusable PP or PET bag | Can be reused repeatedly – approx. 104 times (weekly for 2 years). | Can be recycled at the end of their life (once damaged) through supermarkets. | Not compostable. | Not compostable. | Unlikely to enter the litter stream. | Minimal impact as they are non-degradable. |

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# Appendix 1 – Environmental indicators description

**Table 9 Environmental indicators used in the streamlined LCA study**

| Environmental impact indicator | Description | Unit |
|---|---|---|
| Global warming | Climate change effects resulting from the emission of carbon dioxide ($CO_2$), methane or other global warming gases into the atmosphere – this indicator is represented in $CO_2$ equivalents. | kg $CO_2$ |
| Photochemical oxidation | Measurement of the increased potential of photochemical smog events due to the chemical reaction between sunlight and specific gases released into the atmosphere. These gases include nitrogen oxides (NOx), volatile organic compounds (VOCs), peroxyacyl nitrates (PANs), aldehydes and ozone | kg $C_2H_4$ eq |
| Eutrophication | This is the release of nutrients (mainly phosphorous and nitrogen) into land and water systems, altering biota, and potentially increasing algal growth and related toxic effects. | kg $PO_4^{-3}$ eq |
| Land use | Total exclusive use of land for given time for occupation by the built environment, forestry production and agricultural production processes. | Ha a |
| Water use | Nett water use – potable, process, cooling. Water quality, water depletion, biodiversity. | kL $H_2O$ |
| Solid waste | Solid wastes from production and reprocessing. Impacts depend on character of waste. Mixture of final waste to landfill and production waste from the supply chain. | kg |
| Fossil fuels | The minerals and fuel indicator is similar to the embodied energy indicator. However, it only includes fossil energy and other non-energy mineral depletions. The units for this indicator is the MJ of surplus energy required to provide future mineral and fuel reserves as the quality of existing reserves are depleted. The fossil fuel indicator has been designed on the basis of the Eco-indicator 99 (E) V2.05 assessment method. | MJ surplus |
| Minerals | The additional energy required to extract resources (both mineral and fossil) due to depletion of reserves, leaving lower quality reserves behind. The minerals indicator has been designed from an Eco-Indicator impact assessment method (Eco-indicator 1999 (H) V2.05). | MJ surplus |

**Table 10** presents the description of each of the environmental impact assessment indicator equivalency units

**Table 10 Environmental impact assessment indicator equivalency units.**

| Environmental impact indicator | Description | Equivalency unit |
|---|---|---|
| Global warming | Based on 50g per black balloon, www.saveenergy.vic.gov.au | Number of black balloons |
| Photochemical oxidation | Based on Australian Greenhouse Office (2002), 'National Greenhouse Gas Inventory 2000', Canberra, Australian Greenhouse Office. Assumes 4.1MJ per km energy consumption for passenger car transport. | Metres by car |

| | | |
|---|---|---|
| Eutrophication | Calculation based on the typical P content of household laundry grey water (Total P 3.46mg/L). Source: Sharma,A., Grant, A., Gray, S., Mitchell, G.(2005),'Sustainability of Alternative Water and Sewerage Servicing Options', CSIRO Urban Water & Centre for | Litres of grey water |
| Land use | Number of MCG football areas (20290m2, 2.029Ha a) taken up by activities such as farming, power generation facilities) source: www.mcg.org.au | Number of footy fields |
| Water use | Based on typical household bucket volume of 10litres. | Number of 10 litre buckets |
| Solid waste | Based on the assumption that domestic waste (uncompacted) has a density of 0.131 ton/m^3. (from Better Practice Guide for Waste Management in Multi-Unit Dwellings, http://www.environment.nsw.gov.au/warr/BetterPracticeMUD.htm) | Number of 240 litre wheelie bins |
| Fossil fuels | Unit based on daily household energy use of 51.4GJ/household p.a. average Source: Wilkenfeld, G., (1998), Household Energy Use in Australia, www.energyrating.gov.au | Household electricity per day |
| Minerals | Unit based on daily household energy use of 51.4GJ/household p.a. average Source: Wilkenfeld, G., (1998), Household Energy Use in Australia, www.energyrating.gov.au | Household electricity per day |

# Appendix 2 – Life cycle impact sensitivity analysis

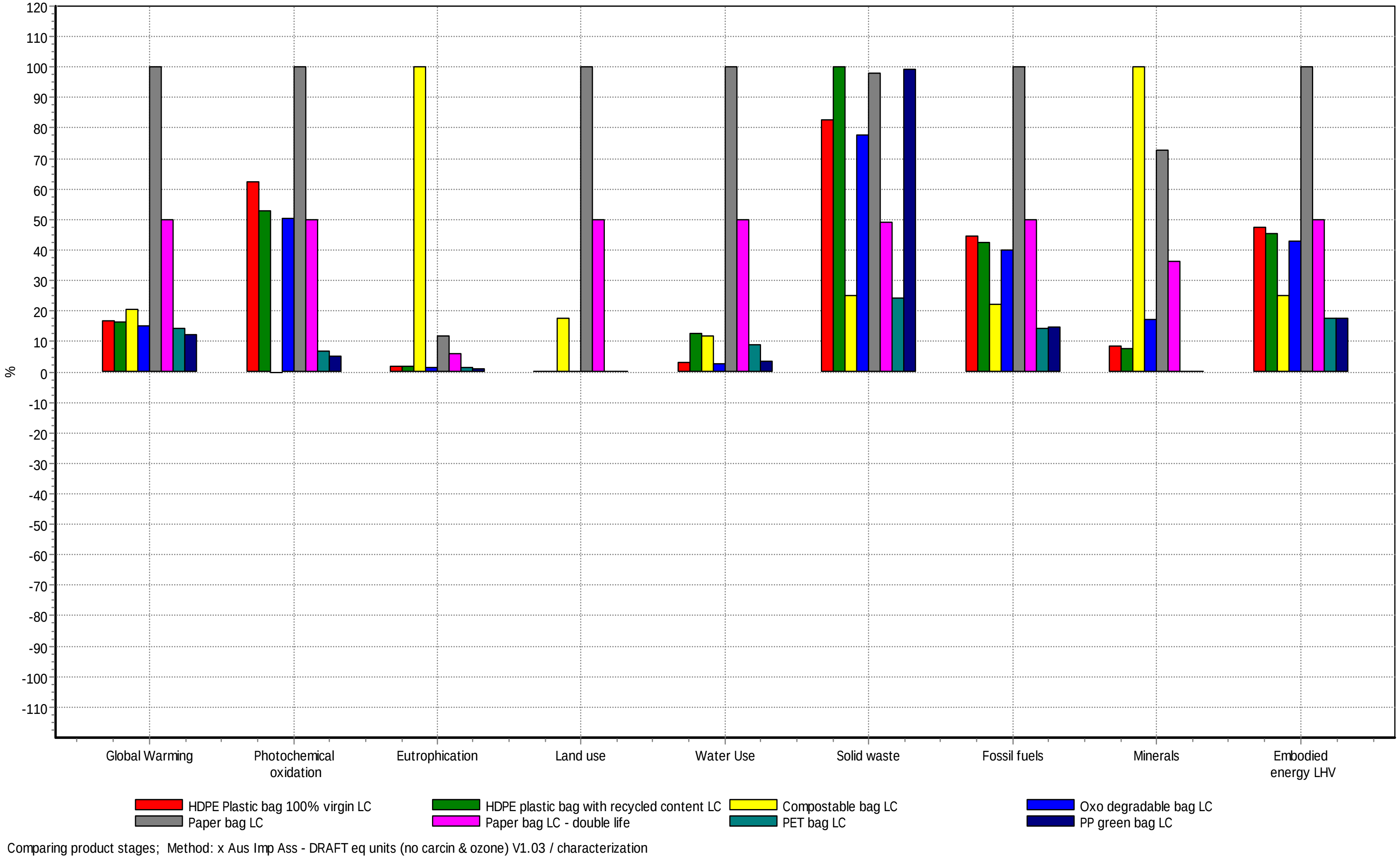
Five sensitivities were performed to obtain an indication on how sensitivity particular data and modelling assumptions were. The sensitivities performed were:

1. Paper bag – single trip baseline versus two trips;
2. Reusable bags – 104 trips baseline versus 52 trips versus 1 trip;
3. HDPE bags – 16% recycling rate baseline versus 30% and 50%;
4. Compostable bag – 10% composting baseline versus 20% and 30%; and
5. Reusable bags – 0% recycling rate baseline versus 10%.

## Table 11 Sensitivity analysis - double use of paper bag

| Impact category | Unit | HDPE Plastic bag 100% virgin | HDPE plastic bag with recycled content | Compostable bag | Oxo degradable bag | Paper bag | Paper bag - double life | PET bag | PP green bag |
|---|---|---|---|---|---|---|---|---|---|
| Global Warming | *kg CO2* | 7.52 | 7.35 | 9.19 | 6.69 | 44.74 | 22.37 | 6.47 | 5.43 |
| | *Bl. Balloons* | 150 | 147 | 184 | 134 | 895 | 447 | 129 | 109 |
| Photochemical oxidation | *kg C2H4* | 0.045 | 0.038 | -0.001 | 0.036 | 0.072 | 0.036 | 0.005 | 0.004 |
| | *m by car* | 56447 | 47959 | -658 | 45561 | 90439 | 45219 | 6362 | 4632 |
| Eutrophication | *kg PO4--- eq* | 0.005 | 0.005 | 0.278 | 0.004 | 0.033 | 0.017 | 0.003 | 0.003 |
| | *L grey water* | 393 | 376 | 22343 | 317 | 2669 | 1334 | 279 | 238 |
| Land use | *Ha a* | 6.627E-06 | 5.945E-06 | 3.489E-04 | 9.158E-07 | 1.992E-03 | 9.960E-04 | 2.033E-06 | 1.320E-06 |
| | *footy fields* | 3.314E-06 | 2.972E-06 | 1.745E-04 | 4.579E-07 | 9.960E-04 | 4.980E-04 | 1.016E-06 | 6.601E-07 |
| Water Use | *KL H2O* | 0.013 | 0.053 | 0.050 | 0.012 | 0.423 | 0.211 | 0.038 | 0.016 |
| | *10L Buckets* | 1.322 | 5.286 | 4.955 | 1.221 | 42.259 | 21.130 | 3.814 | 1.572 |
| Solid waste | *kg* | 2.737 | 3.307 | 0.832 | 2.564 | 3.243 | 1.621 | 0.806 | 3.283 |
| | *240 L bins* | 0.005 | 0.006 | 0.001 | 0.005 | 0.006 | 0.003 | 0.001 | 0.006 |
| Fossil fuels | *MJ surplus* | 19.927 | 19.067 | 9.964 | 17.937 | 44.771 | 22.385 | 6.463 | 6.646 |
| | *Househ E*d* | 0.139 | 0.133 | 0.070 | 0.126 | 0.313 | 0.157 | 0.045 | 0.047 |
| Minerals | *MJ Surplus* | 8.445E-04 | 7.786E-04 | 1.018E-02 | 1.735E-03 | 7.423E-03 | 3.711E-03 | 3.388E-05 | 2.497E-05 |
| | *Househ E*d* | 5.912E-06 | 5.450E-06 | 7.125E-05 | 1.215E-05 | 5.196E-05 | 2.598E-05 | 2.372E-07 | 1.748E-07 |

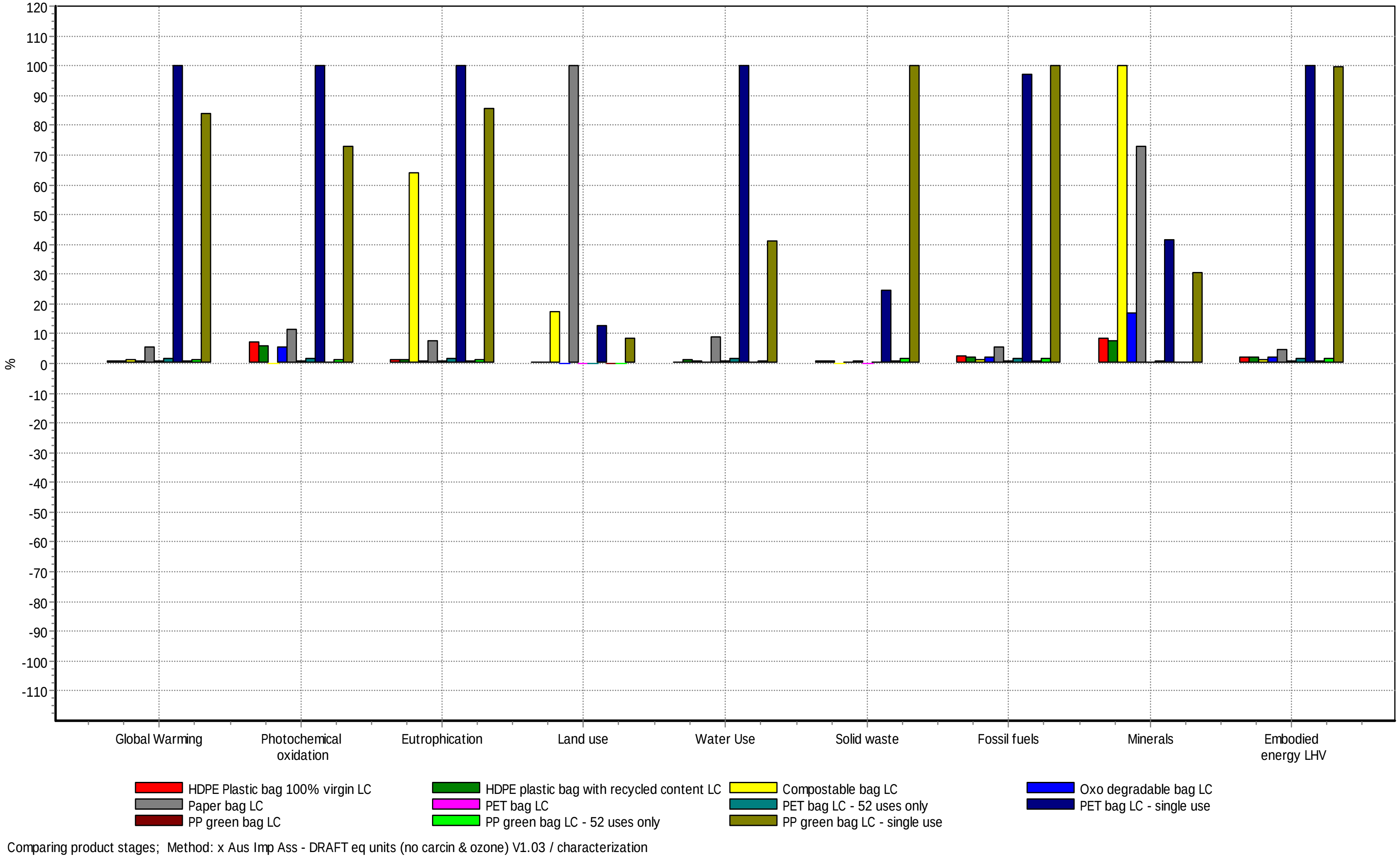
## Figure 6: Sensitivity analysis – double use of paper bags



## Table 12: Sensitivity analysis – reusable bag trips

| Impact category | Unit | HDPE Plastic bag 100% virgin | HDPE plastic bag with recycled content | Compost-able bag | Oxo degrade-able bag | Paper bag | PET bag | PET bag - 52 uses only | PET bag - single use | PP green bag | PP green bag - 52 uses only | PP green bag - single use |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Global Warming | *kg CO2* | 7.52 | 7.35 | 9.19 | 6.69 | 44.74 | 6.47 | 12.94 | 810.78 | 5.43 | 10.86 | 680.11 |
| | *Bl. Balloons* | 150 | 147 | 184 | 134 | 895 | 129 | 259 | 16216 | 109 | 217 | 13602 |
| Photo-chemical oxidation | *kg C2H4* | 0.045 | 0.038 | -0.001 | 0.036 | 0.072 | 0.005 | 0.010 | 0.634 | 0.004 | 0.007 | 0.462 |
| | *m by car* | 56447 | 47959 | -658 | 45561 | 90439 | 6362 | 12713 | 796491 | 4632 | 9265 | 580389 |
| Eutroph-ication | *kg PO4--- eq* | 0.005 | 0.005 | 0.278 | 0.004 | 0.033 | 0.003 | 0.007 | 0.435 | 0.003 | 0.006 | 0.372 |
| | *L grey water* | 393 | 376 | 22343 | 317 | 2669 | 279 | 557 | 34896 | 238 | 476 | 29839 |
| Land use | *Ha a* | 6.627E-06 | 5.945E-06 | 3.489E-04 | 9.158E-07 | 1.992E-03 | 2.033E-06 | 4.059E-06 | 2.547E-04 | 1.320E-06 | 2.641E-06 | 0.0002 |
| | *footy fields* | 3.314E-06 | 2.972E-06 | 1.745E-04 | 4.579E-07 | 9.960E-04 | 1.016E-06 | 7.627E+00 | 1.27E-04 | 6.601E-07 | 1.320E-06 | 8.25E-05 |
| Water Use | *KL H2O* | 0.013 | 0.053 | 0.050 | 0.012 | 0.423 | 0.038 | 0.076 | 4.779 | 0.016 | 0.031 | 1.970 |
| | *10L Buckets* | 1.322 | 5.286 | 4.955 | 1.221 | 42.26 | 3.814 | 7.630 | 477.8 | 1.572 | 3.145 | 197.0 |
| Solid waste | *Kg* | 2.737 | 3.307 | 0.832 | 2.564 | 3.243 | 0.806 | 1.612 | 101.0 | 3.283 | 6.566 | 411.4 |
| | *240 L bins* | 0.005 | 0.006 | 0.001 | 0.005 | 0.006 | 0.001 | 0.003 | 0.182 | 0.006 | 0.019 | 0.740 |
| Fossil fuels | *MJ surplus* | 19.927 | 19.067 | 9.964 | 17.937 | 44.771 | 6.463 | 12.93 | 809.8 | 6.646 | 13.29 | 832.7 |
| | *Househ E*d* | 0.139 | 0.133 | 0.070 | 0.126 | 0.313 | 0.045 | 0.091 | 5.668 | 0.047 | 0.093 | 5.829 |
| Minerals | *MJ Surplus* | 8.445E-04 | 7.786E-04 | 1.018E-02 | 1.735E-03 | 7.423E-03 | 3.388E-05 | 6.780E-05 | 4.246E-03 | 2.497E-05 | 4.99E-05 | 2.932E-04 |
| | *Househ E*d* | 5.912E-06 | 5.450E-06 | 7.125E-05 | 1.215E-05 | 5.196E-05 | 2.372E-07 | 4.744E-07 | 2.972E-05 | 1.748E-07 | 3.496E-07 | 2.05E-06 |

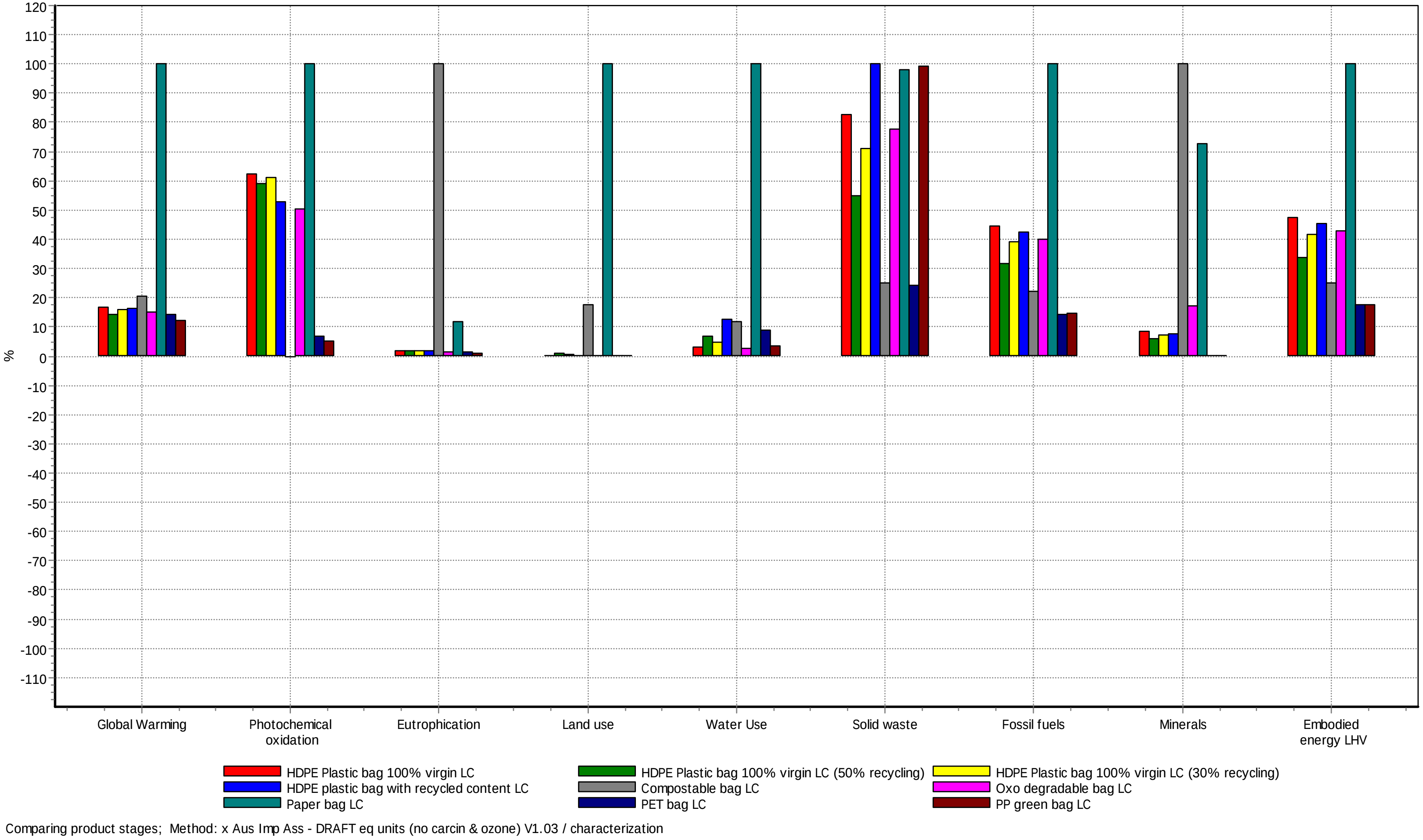
## Figure 7: Sensitivity analysis – reusable bag trips



## Table 13: Sensitivity analysis - different HDPE recycling rates

| **Impact category** | **Unit** | **HDPE Plastic bag 100% virgin** | **HDPE Plastic bag 100% virgin (50% recycling)** | **HDPE Plastic bag 100% virgin (30% recycling)** | **HDPE plastic bag with recycled content** | **Compost-able bag** | **Oxo degradable bag** | **Paper bag** | **PET bag** | **PP green bag** |
|---|---|---|---|---|---|---|---|---|---|---|
| Global Warming | *kg CO2* | 7.52 | 6.47 | 7.09 | 7.35 | 9.19 | 6.69 | 44.74 | 6.47 | 5.43 |
|  | *Bl. Balloons* | 150 | 129 | 142 | 147 | 184 | 134 | 895 | 129 | 109 |
| Photochemical oxidation | *kg C2H4* | 0.045 | 0.042 | 0.044 | 0.038 | -0.001 | 0.036 | 0.072 | 0.005 | 0.004 |
|  | *m by car* | 56447 | 53268 | 55138 | 47959 | -658 | 45561 | 90439 | 6362 | 4632 |
| Eutrophication | *kg PO4--- eq* | 0.005 | 0.005 | 0.005 | 0.005 | 0.278 | 0.004 | 0.033 | 0.003 | 0.003 |
|  | *L grey water* | 393 | 388 | 391 | 376 | 22343 | 317 | 2669 | 279 | 238 |
| Land use | *Ha a* | 6.627E-06 | 1.856E-05 | 1.154E-05 | 5.945E-06 | 3.489E-04 | 9.158E-07 | 1.992E-03 | 2.033E-06 | 1.320E-06 |
|  | *footy fields* | 3.314E-06 | 9.280E-06 | 5.770E-06 | 2.972E-06 | 1.745E-04 | 4.579E-07 | 9.960E-04 | 1.016E-06 | 6.601E-07 |
| Water Use | *KL H2O* | 0.013 | 0.030 | 0.020 | 0.053 | 0.050 | 0.012 | 0.423 | 0.038 | 0.016 |
|  | *10L Buckets* | 1.322 | 2.963 | 1.998 | 5.286 | 4.955 | 1.221 | 42.26 | 3.814 | 1.572 |
| Solid waste | *kg* | 2.737 | 1.815 | 2.357 | 3.307 | 0.832 | 2.564 | 3.243 | 0.806 | 3.283 |
|  | *240 L bins* | 0.005 | 0.003 | 0.004 | 0.006 | 0.001 | 0.005 | 0.006 | 0.001 | 0.006 |
| Fossil fuels | *MJ surplus* | 19.927 | 14.216 | 17.575 | 19.067 | 9.964 | 17.937 | 44.771 | 6.463 | 6.646 |
|  | *Househ E*d* | 0.139 | 0.100 | 0.123 | 0.133 | 0.070 | 0.126 | 0.313 | 0.045 | 0.047 |
| Minerals | *MJ Surplus* | 8.445E-04 | 5.990E-04 | 7.435E-04 | 7.786E-04 | 1.018E-02 | 1.735E-03 | 7.423E-03 | 3.388E-05 | 2.497E-05 |
|  | *Househ E*d* | 5.912E-06 | 4.193E-06 | 5.204E-06 | 5.450E-06 | 7.125E-05 | 1.215E-05 | 5.196E-05 | 2.372E-07 | 1.748E-07 |

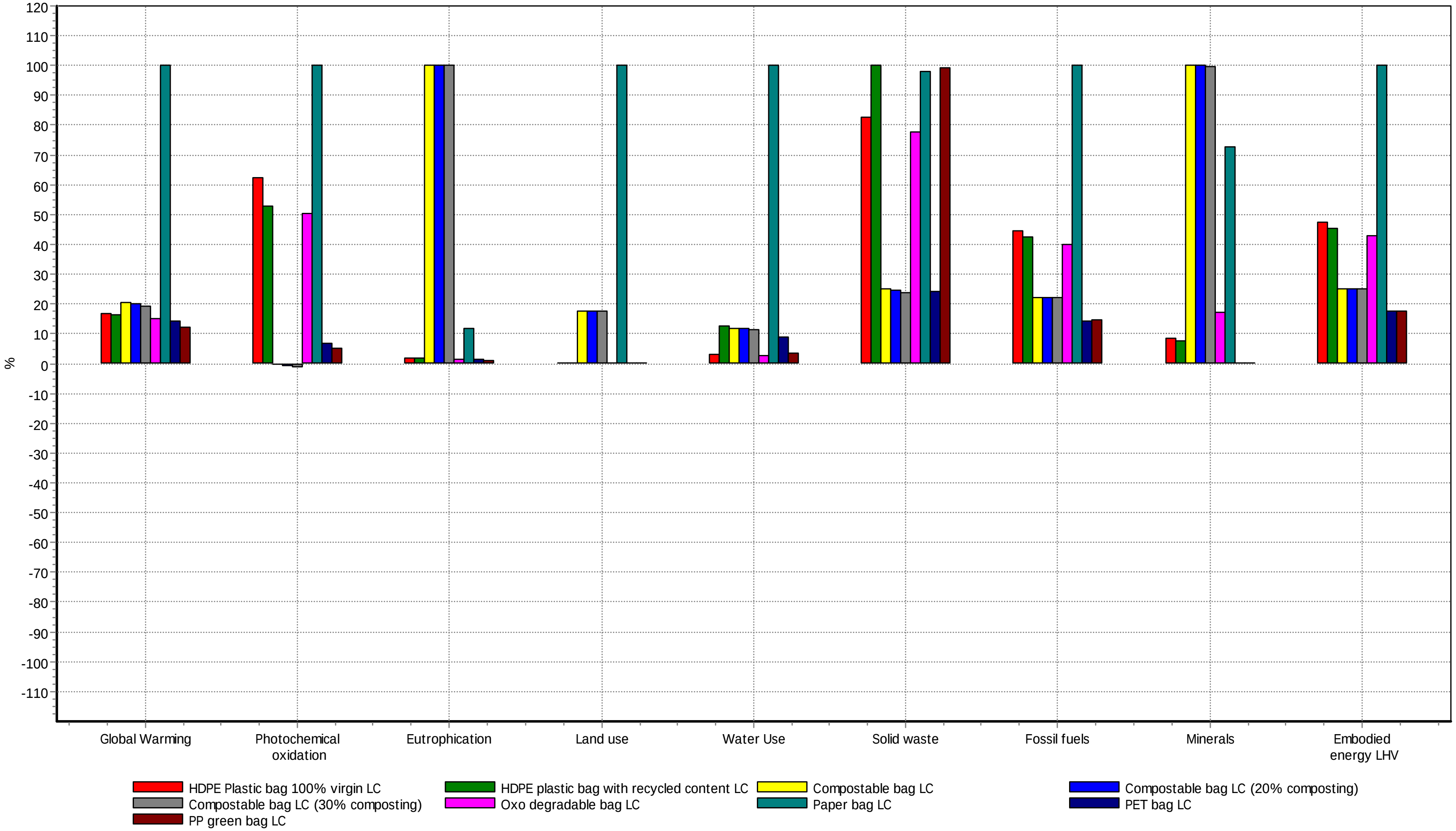
## Figure 8: Sensitivity analysis - different HDPE recycling rates



## Table 14: Sensitivity analysis - different composting rates for the compostable bag

| Impact category | Unit | HDPE Plastic bag 100% virgin | HDPE plastic bag with recycled content | Compostable bag | Compostable bag (20% composting) | Compostable bag (30% composting) | Oxo-degradable bag | Paper bag | PET bag | PP green bag |
|---|---|---|---|---|---|---|---|---|---|---|
| Global Warming | *kg CO2* | 7.52 | 7.35 | 9.19 | 8.92 | 8.66 | 6.69 | 44.74 | 6.47 | 5.43 |
| | *Bl. Balloons* | 150 | 147 | 184 | 178 | 173 | 134 | 895 | 129 | 109 |
| Photochemical oxidation | *kg C2H4* | 0.045 | 0.038 | -0.001 | -0.001 | -0.001 | 0.036 | 0.072 | 0.005 | 0.004 |
| | *m by car* | 56447 | 47959 | -658 | -939 | -1220 | 45561 | 90439 | 6362 | 4632 |
| Eutrophication | *kg PO4--- eq* | 0.005 | 0.005 | 0.278 | 0.278 | 0.278 | 0.004 | 0.033 | 0.003 | 0.003 |
| | *L grey water* | 393 | 376 | 22343 | 22339 | 22336 | 317 | 2669 | 279 | 238 |
| Land use | *Ha a* | 6.627E-06 | 5.945E-06 | 3.489E-04 | 3.480E-04 | 3.471E-04 | 9.158E-07 | 1.992E-03 | 2.033E-06 | 1.320E-06 |
| | *footy fields* | 3.314E-06 | 2.972E-06 | 1.745E-04 | 1.740E-04 | 1.735E-04 | 4.579E-07 | 9.960E-04 | 1.016E-06 | 6.601E-07 |
| Water Use | *KL H2O* | 0.013 | 0.053 | 0.050 | 0.049 | 0.049 | 0.012 | 0.423 | 0.038 | 0.016 |
| | *10L Buckets* | 1.322 | 5.286 | 4.955 | 4.918 | 4.882 | 1.221 | 42.26 | 3.814 | 1.572 |
| Solid waste | *kg* | 2.737 | 3.307 | 0.832 | 0.813 | 0.795 | 2.564 | 3.243 | 0.806 | 3.283 |
| | *240 L bins* | 0.005 | 0.006 | 0.001 | 0.001 | 0.001 | 0.005 | 0.006 | 0.001 | 0.006 |
| Fossil fuels | *MJ surplus* | 19.927 | 19.067 | 9.964 | 9.954 | 9.945 | 17.937 | 44.771 | 6.463 | 6.646 |
| | *Househ E*d* | 0.139 | 0.133 | 0.070 | 0.070 | 0.070 | 0.126 | 0.313 | 0.045 | 0.047 |
| Minerals | *MJ Surplus* | 8.445E-04 | 7.786E-04 | 1.018E-02 | 1.017E-02 | 1.017E-02 | 1.735E-03 | 7.423E-03 | 3.388E-05 | 2.497E-05 |
| | *Househ E*d* | 5.912E-06 | 5.450E-06 | 7.125E-05 | 7.121E-05 | 7.116E-05 | 1.215E-05 | 5.196E-05 | 2.372E-07 | 1.748E-07 |

## Figure 9: Sensitivity analysis - different composting rates for the compostable bag

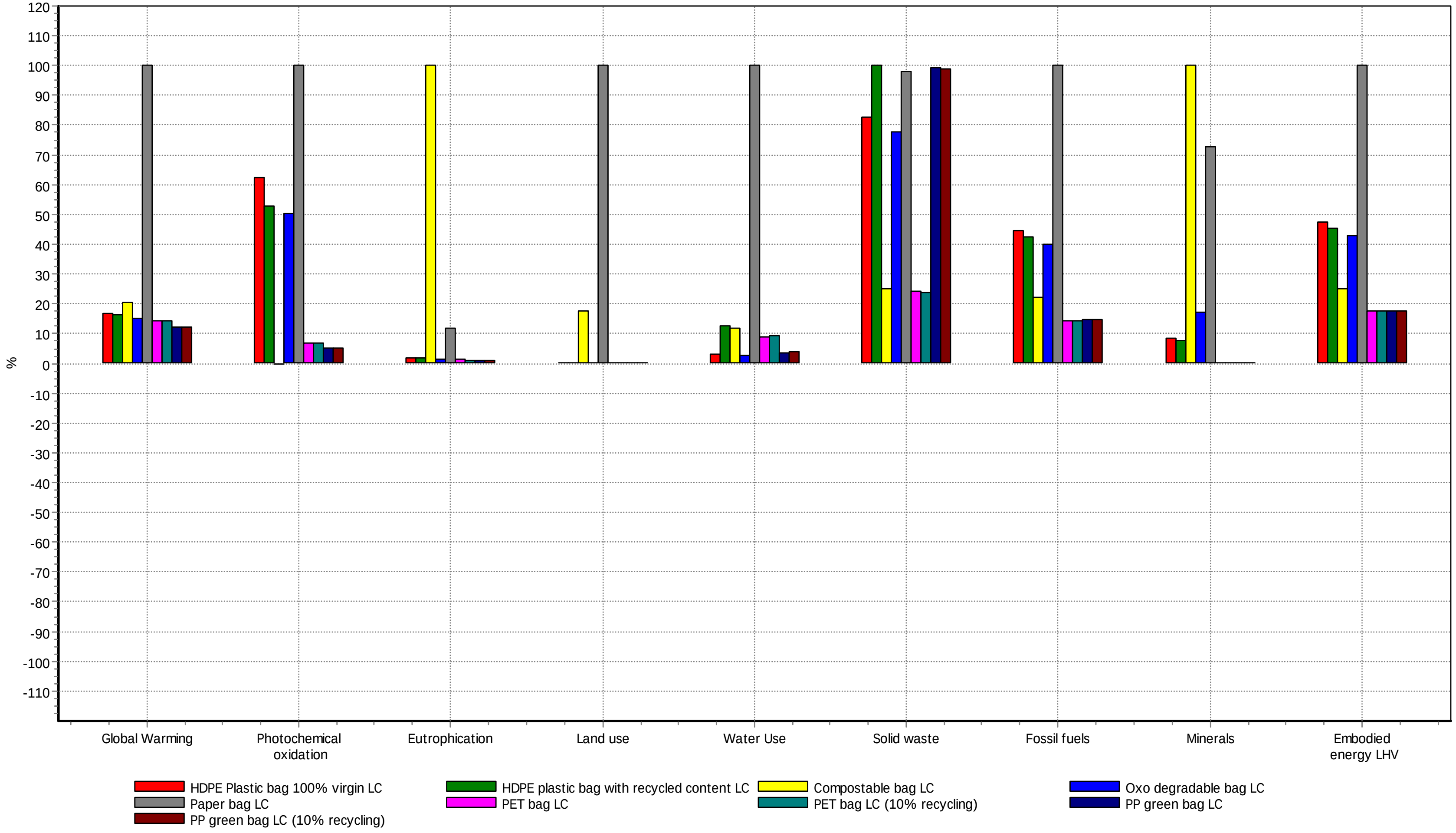


Comparing product stages; Method: x Aus Imp Ass - DRAFT eq units (no carcin & ozone) V1.03 / characterization

## Table 15: Sensitivity analysis - recycling reusable bags at end of life

| **Impact category** | **Unit** | **HDPE Plastic bag 100% virgin** | **HDPE plastic bag with recycled content** | **Compostable bag** | **Oxo degradable bag** | **Paper bag** | **PET bag** | **PET bag (10% recycling)** | **PP green bag** | **PP green bag (10% recycling)** |
|---|---|---|---|---|---|---|---|---|---|---|
| Global Warming | *kg CO2* | 7.52 | 7.35 | 9.19 | 6.69 | 44.74 | 6.47 | 6.46 | 5.43 | 5.40 |
| | *Bl. Balloons* | 150 | 147 | 184 | 134 | 895 | 129 | 129 | 109 | 108 |
| Photochemical oxidation | *kg C2H4* | 0.045 | 0.038 | -0.001 | 0.036 | 0.072 | 0.005 | 0.005 | 0.004 | 0.004 |
| | *m by car* | 56447 | 47959 | -658 | 45561 | 90439 | 6362 | 6296 | 4632 | 4542 |
| Eutrophication | *kg PO4--- eq* | 0.005 | 0.005 | 0.278 | 0.004 | 0.033 | 0.003 | 0.003 | 0.003 | 0.003 |
| | *L grey water* | 393 | 376 | 22343 | 317 | 2669 | 279 | 276 | 238 | 237 |
| Land use | *Ha a* | 6.627E-06 | 5.945E-06 | 3.489E-04 | 9.158E-07 | 1.992E-03 | 2.033E-06 | 2.027E-06 | 1.320E-06 | 1.320E-06 |
| | *footy fields* | 3.314E-06 | 2.972E-06 | 1.745E-04 | 4.579E-07 | 9.960E-04 | 1.016E-06 | 1.010E-06 | 6.601E-07 | 6.601E-07 |
| Water Use | *KL H2O* | 0.013 | 0.053 | 0.050 | 0.012 | 0.423 | 0.038 | 0.039 | 0.016 | 0.017 |
| | *10L Buckets* | 1.322 | 5.286 | 4.955 | 1.221 | 42.26 | 3.814 | 3.934 | 1.572 | 1.686 |
| Solid waste | *kg* | 2.737 | 3.307 | 0.832 | 2.564 | 3.243 | 0.806 | 0.792 | 3.283 | 3.264 |
| | *240 L bins* | 0.005 | 0.006 | 0.001 | 0.005 | 0.006 | 0.001 | 0.001 | 0.006 | 0.006 |
| Fossil fuels | *MJ surplus* | 19.93 | 19.07 | 9.964 | 17.94 | 44.77 | 6.463 | 6.388 | 6.646 | 6.537 |
| | *Househ E*d* | 0.139 | 0.133 | 0.070 | 0.126 | 0.313 | 0.045 | 0.045 | 0.047 | 0.046 |
| Minerals | *MJ Surplus* | 8.445E-04 | 7.786E-04 | 1.018E-02 | 1.735E-03 | 7.423E-03 | 3.388E-05 | 3.389E-05 | 2.497E-05 | 2.493E-05 |
| | *Househ E*d* | 5.912E-06 | 5.450E-06 | 7.125E-05 | 1.215E-05 | 5.196E-05 | 2.372E-07 | 2.373E-07 | 1.748E-07 | 1.743E-07 |

## Figure 10: Sensitivity analysis - Recycling reusable bags at end of life



Comparing product stages; Method: x Aus Imp Ass - DRAFT eq units (no carcin & ozone) V1.03 / characterization