

## CARRIER BAG LIFE-CYCLE ASSESSMENT (LCA) RESEARCH REVIEW

### Introduction

Life-cycle assessment (LCA) is intended as a tool for assessing and improving the environmental performance of the product or service in question. The Industry Council for Packaging and the Environment (INCPEN) recognises in its *Lifecycle and Carbon Measurement: Limitations* fact sheet (see [www.incpen.org/displayarticle.asp?a=15&c=2](http://www.incpen.org/displayarticle.asp?a=15&c=2)), that LCA's use a comparative tool to assess which carrier bag type is environmentally superior should be treated with caution owing to the key importance on the study results of the assumptions, boundaries, etc., that are set at the outset.

Notwithstanding this limitation, this letter report summarises the findings of key existing LCA research that has been undertaken by third parties in relation to the environmental impact of different types of carrier bag.

**Life Cycle Assessment of Supermarket Carrier Bags, Report: SC030148, Environment Agency, February 2011** (see [www.environment-agency.gov.uk/research/library/publications/129364.aspx](http://www.environment-agency.gov.uk/research/library/publications/129364.aspx))

This study assesses the life-cycle environmental impacts of the production, use and disposal of different carrier bags for the UK. In recent years, the relative environmental impacts of lightweight carrier bags and other options have been debated. By spring 2009, leading supermarkets had halved the number of single-use carrier bags being used. However, questions still remain about the environmental significance of lightweight carrier bags, especially with regard to the wider debate on global warming.

The report considers only the types of carrier bag available from UK supermarkets. It does not examine personal bags or carriers given out by other high-street retailers. The report does not consider the introduction of a carrier bag tax; the effects of littering; the ability and willingness of consumers to change their behaviour; any adverse impacts of degradable polymers in the recycling stream; or the potential economic impacts on UK business.

The following types of carrier bag were studied:

- conventional, lightweight bags made from high-density polyethylene (HDPE)
- lightweight HDPE bags containing a prodegradant additive designed to break the down the plastic into smaller pieces
- biodegradable bags made from a starch–polyester (biopolymer) blend
- paper bags
- “bags for life” made from low-density polyethylene (LDPE)
- heavier more durable bags, often with stiffening inserts made from nonwoven polypropylene (PP)
- cotton bags.

To make the comparison fair, the study considered impacts from the number of bags required to carrying one month's shopping in 2006/07. It calculated how many times each different type of carrier would have to be used to reduce its global warming potential to below that for conventional HDPE carrier bags, where some 40% are reused as bin liners. Finally, the bags were compared for other impacts: resource depletion, acidification, eutrophication, human toxicity, freshwater aquatic ecotoxicity, marine aquatic ecotoxicity, terrestrial ecotoxicity and photochemical oxidation (smog formation).

The study found that

- the environmental impact of all types of carrier bag is dominated by resource use and production stages. Transport, secondary packaging and end-of-life management generally have a minimal influence on their performance.
- Whatever type of bag is used, the key to reducing the impacts is to reuse it as many times as possible and, where reuse for shopping is not practicable, other reuse options, e.g., to replace bin liners, are beneficial.
- The reuse of conventional HDPE and other lightweight carrier bags for shopping and/or as bin liners is pivotal to their environmental performance. Their reuse as bin liners produces greater benefits than recycling of bags.
- Starch–polyester blend bags have a higher global warming potential and abiotic depletion than conventional polymer bags. This is due both to the increased weight of material in a bag and the higher material production impacts.
- Paper, LDPE, nonwoven PP and cotton bags should be reused at least 3, 4, 11 and 131 times respectively to ensure that they have lower global warming potential than conventional HDPE carrier bags that are not reused. The number of times each would have to be reused when different proportions of conventional (HDPE) carrier bags are reused is shown in Table 1.
- Recycling and composting generally produce only a small reduction in global warming potential and abiotic depletion.

**Proposed Plastic Bag Levy – Extended Impact Assessment, Volume 1, main report, Scottish Government, 2005–2006** (see [www.scotland.gov.uk/publications/2005/08/1993102/31045](http://www.scotland.gov.uk/publications/2005/08/1993102/31045))

MSP Mike Pringle tabled a member’s bill in the Scottish Parliament to impose an environmental levy on specified plastic bags. If passed, this legislation aimed to cover all plastic bags provided by retailers at the point of sale or from other outlets. The inspiration for this bill was taken from the experience of the plastic bags levy (the so-called PlasTax) in the Republic of Ireland.

The Scottish Executive commissioned a study from AEA Technology Environment and associates to address the likely impacts of such a levy and variants of it on

- the environment
- consumers
- business
- waste
- local authorities.

Advocates of a levy on plastic bags cite the main benefits as being reduced littering (including marine litter), reduced use of resources and energy, lower pollutant emissions and increased public awareness of environmental issues. Opponents argue that lightweight plastic carrier bags are hygienic, convenient and durable; that they are often reused for other purposes; that they form only a small part of the litter stream; and that they have a lower overall environmental impact than paper bags. They also claim that a levy would impact unfairly on poorer households and would lead to job losses in Scotland from reduced plastic bag manufacturing and importing. The study considered these and other arguments for and against a levy, and quantified the probable effects wherever possible.

This study used an existing published life-cycle study from France to gain an indication of the relative life-cycle environmental impacts of different types of bag. This was then combined with estimates of changes in bag use under four levy scenarios to examine the resulting changes in environmental impacts from bag usage.

Using the Carrefour study introduced an element of uncertainty into the results owing to national differences between Scotland and France affecting bag life cycle, i.e., the way in which electricity is generated, the amount of transport required and the final disposal methods.

However, on the basis of the results of sensitivity analyses, the pattern of environmental impacts described in the Carrefour study was considered to be similar to that in Scotland and, therefore, the results were felt to be sufficiently relevant to serve as a useful guide to decision making on policies concerning carrier bags. However, for the reasons presented above, the findings in this report cannot be used for a precise quantification of environmental impacts. This would require a full LCA based on the Scottish situation, which was outside the scope of the study.

The main conclusions of this analysis are as follows:

- The biggest environmental improvement is seen where paper bags are included in the levy. These occur for all environmental indicators.
- In scenarios where paper bags are excluded, the environmental benefits of reduced plastic bag usage are negated for some indicators by the impacts of increased paper bag usage. This is because a paper bag has a more adverse impact than a plastic bag for most of the environmental issues considered. Areas where paper bags score particularly badly include water consumption; acidification, which can have negative effects on human health, sensitive ecosystems, forest decline and lakes; and eutrophication of water bodies, which can lead to the growth of algae and the depletion of oxygen.
- Heavyweight, reusable plastic bags (the so-called bags for life) are more sustainable than all types of lightweight plastic carrier bags if used four times or more. They give the greatest environmental benefits over the full life cycle.
- Paper bags are any 6–10 times heavier than lightweight plastic carrier bags and, consequently, require more transport with its associated costs. They would also take up more room in a landfill if they were not recycled.
- The analysis demonstrates that paper bags should be included to maximise the potential environmental benefit of the levy.

**Study for Carrefour by PriceWaterhouseCoopers and Ecobilan** (see [www.ademe.fr/htdocs/actualite/rapport\\_carrefour\\_post\\_revue\\_critique\\_v4.pdf](http://www.ademe.fr/htdocs/actualite/rapport_carrefour_post_revue_critique_v4.pdf))

The starting point for the Scottish Government analysis is a series of tables in the Carrefour report that show the relative performance of different types of bag against each of the indicators considered and that assumes all bags are sent to landfill at the end of their lives.

*Table 1: Relative performance of different types of carrier bag against environmental indicators.*

| Indicator of environmental impact             | HDPE bag (lightweight) | Reusable LDPE bag (used 2x) | Reusable LDPE bag (used 4x) | Reusable LDPE bag (used 20x) | Paper bag (single use) |
|---|------------------------|-----------------------------|-----------------------------|------------------------------|------------------------|
| Consumption of non-renewable primary energy   | 1.0                    | 1.4                         | 0.7                         | 0.1                          | 1.1                    |
| Consumption of water                          | 1.0                    | 1.3                         | 0.6                         | 0.1                          | 4.0                    |
| Climate change (emission of greenhouse gases) | 1.0                    | 1.3                         | 0.6                         | 0.1                          | 3.3                    |
| Acid rain (atmospheric acidification)         | 1.0                    | 1.5                         | 0.7                         | 0.1                          | 1.9                    |
| Air quality (ground level ozone formation)    | 1.0                    | 0.7                         | 0.3                         | 0.1                          | 1.3                    |
| Eutrophication of water bodies                | 1.0                    | 1.4                         | 0.7                         | 0.1                          | 14.0                   |
| Solid waste production                        | 1.0                    | 1.4                         | 0.7                         | 0.1                          | 2.7                    |
| Risk of litter                                | 1.0                    | 0.4                         | 0.4                         | 0.4                          | 0.2                    |

The results show that paper bags perform worse in all indicators except risk of litter. Reusable bags perform best, provided that they are reused at least four times.

**Plastic Shopping Bags – Analysis of Levies and Environmental Impacts: Final Report, Environment Australia, Department of the Environment and Heritage, 2002** (see [www.environment.gov.au/archive/settlements/publications/waste/plastic-bags/pubs/analysis.pdf](http://www.environment.gov.au/archive/settlements/publications/waste/plastic-bags/pubs/analysis.pdf))

The key findings of the environmental assessment aspect of this study showed that

- a substantial shift from single-use disposable bags to more durable reusable bags would deliver an environmental gain over the full life cycle of the packaging

- less significant and consistent gains would be made by switching from HDPE to other single-use bags, such as paper and biodegradable bags, with potential gains in litter being offset by negative resource use outcomes
- there were no significant differences in reusable bag environmental outcomes. Reusable heavy-duty plastic bags, which can combine low resource use, longevity and recycling, came out on top.
- the use of biodegradable bags would offer some benefits in litter persistence but would not deliver significant resource use gains and would not be compatible with plastic bag recycling
- the environmental gains from reusable bags are closely linked to the life expectancy of the bags, their weight-to-capacity ratio and their final destination – low litter, high recycle.

**Resource and Environmental Profile Analysis of Polyethylene and Unbleached Paper Grocery Sacks, Franklin Associates** (see <http://plastics.americanchemistry.com/education-resources/publications/resource-and-environmental-profile-analysis-of-polyethylene-and-unbleached-paper-grocery-sacks.pdf>)

The purpose of this US study was to determine the energy and environmental discharges of polyethylene and paper grocery sacks. The term impact refers to the quantities of fuel and raw materials consumed and emissions released to the environment. The comparative recyclability, incineration and landfill impacts of these sacks were also addressed in this analysis.

The packages examined in this study were chosen because of their predominant visibility and potential for restrictive legislation. The following packages were examined:

- $\frac{1}{6}$ -barrel polyethylene grocery sacks
- $\frac{1}{6}$ -barrel, 70-lb base weight, single-ply, unbleached paper grocery sacks.

These sacks are the standard plastic and paper sacks used in US grocery stores. The results for the polyethylene sacks represented both high-molecular-weight high-density polyethylene (HMW-HDPE) and linear LDPE resins. The term package was used throughout this study to mean the grocery sack itself and all secondary packaging such as overwrap and corrugated boxes.

The two sacks examined in this study were the same size. However, through surveys of major grocery chains, it was determined that more plastic sacks than paper sacks are used to hold the same amount of groceries. The practice of using more plastic compared with paper sacks is believed to hold true even after taking into account some stores' practice of using double (one sack inside the other) paper sacks. One reason for the use of more plastic sacks seems to be inexperience on the part of grocery clerks and consumers on how to pack them so that they may hold their designed capacity. Another reason for the use of more plastic sacks could also be a mistaken comparison of smaller plastic sacks, for instance,  $\frac{1}{7}$ -barrel plastic to the standard  $\frac{1}{6}$ -barrel paper sack.

As the ratio of polyethylene sacks to paper sacks used was crucial to the results of this study, considerable effort was made to determine this number. Ratios ranging from 1.2:1 to 3:1 have been reported, but there is no industry-wide agreement on a representative ratio. Therefore, the results of this analysis were presented at ratios of 1.5:1 and 2:1 polyethylene to paper, most estimates fall within this range. These ratios were developed based on data collected from supermarket chains and other industry sources.

The key findings of this research are as follows:

- The energy requirements for plastic polyethylene grocery sacks are 20–40% less than for paper sacks at zero percent recycling for both sacks.

- As recycling increases for plastic polyethylene and paper sacks at the 2 PE to 1 paper sack ratio, the energy requirements become equivalent at approximately a 60% recycling rate.
- At the 1.5 PE to 1 paper sack ratio, the polyethylene sack continues to require 23% less energy than paper, even at 100% recycling.
- Polyethylene sacks contribute 74–80% less solid waste than paper sacks at zero percent recycling. Polyethylene sacks continue to contribute less solid waste than paper sacks at all recycling rates.
- Atmospheric emissions for polyethylene sacks range from 63 to 73% less than for the paper sacks at zero percent recycling. These lower impacts for the polyethylene sacks continue throughout all recycling rates.
- At a zero percent recycling rate, the polyethylene sack contributes over 90% less waterborne wastes than the paper sacks. This percentage difference actually increases as the recycling rates for both grocery sacks increase.
- Both polyethylene and paper sacks are recyclable. Manufacturing and scrap trim from the fabrication of the sacks are typically recycled. Post-consumer recycling for both of these has not been significant. In the case of paper sacks, they are most typically recycled during the collection of old newspapers. For polyethylene sacks, efforts are usually concentrated on industrial scrap film. However, significant initiatives have recently begun to collect both polyethylene and paper grocery sacks at the post-consumer level.
- On a by-weight basis, polyethylene releases 2.75 times more energy on incineration than unbleached paper. However, on an equal-use basis, paper grocery sacks weigh 4–5 times more than polyethylene grocery sacks. Therefore, on an equivalent-use basis, the paper sack has a greater potential for energy release during incineration than the polyethylene sack.
- The ash content per pound of unbleached paper is greater than that of polyethylene. Thus, even on an equivalent-use basis, the paper sack has a greater potential for more ash from incineration than the polyethylene sack.
- The landfill volume occupied by the polyethylene sacks is 70–80% less than the volume occupied by paper sacks on 10,000 uses.
- Although some degradation occurs in landfills, little data exists regarding what materials degrade and their rate of decomposition. Therefore, the degradability of both paper and polyethylene grocery sacks cannot be predicted. Consequently, no estimates can be made regarding the potential for impact on landfill leachate or methane gas production.

**Review of Life Cycle Data Relating to Disposable, Compostable, Biodegradable, and Reusable Grocery Bags, Use Less Stuff, 2008** (see <http://use-less-stuff.com/paper-and-plastic-grocery-bag-lca-summary-3-28-08.pdf>)

The key findings of this research are as follows and are based on the fact that it is generally accepted that 1.5 plastic bags equal the capacity of 1 paper bag:

- Although paper and certain plastics may be biodegradable or compostable in specially designed industrial facilities, evidence indicates that this feature may be of little value in the effort to reduce waste. Current research shows that in modern landfills paper does not degrade or break down substantially faster than plastic. Owing to the lack of water, light, oxygen and other important elements necessary for biodegradation to occur, nothing completely degrades in modern landfills.
- The evidence does not support conventional wisdom that paper bags are a more environmentally sustainable alternative than plastic bags:
  - Plastic bags generate 39% less greenhouse gas emissions than un-composted paper bags, and 68% less greenhouse gas emissions than composted paper bags.
  - Plastic bags generate 4645 US tons (4214 metric tonnes) of carbon dioxide equivalent per 150 million bags, whereas un-composted paper bags generate

7621 US tons (6914 metric tonnes) and composted paper bags generate 14,558 US tons (13,207 metric tonnes) per 100 million bags produced.

- Plastic bags consume less than 6% of the water needed to make paper bags. It takes 1004 US gallons (3.8 m<sup>3</sup>) of water to produce 1000 paper bags and 58 US gallons (0.2 m<sup>3</sup>) of water to produce 1500 plastic bags.
- Plastic grocery bags consume 71% less energy during production than paper bags.
- Even though traditional disposable plastic bags are produced from fossil fuels, the total non-renewable energy consumed during their life cycle is up to 36% less than the non-renewable energy consumed during the life cycle of paper bags and up to 64% less than that consumed by biodegradable plastic bags.
- Using paper sacks generates almost five times more solid waste than using plastic bags.
- After four or more uses, reusable plastic bags are superior to all types of disposable bags, paper, PE and compostable plastic, across all significant environmental indicators.

### Key summary points

- Plastic bags generate 39% less greenhouse gas emissions than un-composted paper bags and 68% less greenhouse gas emissions than composted paper bags.
- Plastic grocery bags consume 71% less energy during production than paper bags.
- Even though traditional disposable plastic bags are produced from fossil fuels, the total non-renewable energy consumed during their life cycle is up to 36% less than the non-renewable energy consumed during the life cycle of paper bags and up to 64% less than that consumed by biodegradable plastic bags.
- Using paper bags generates almost five times more solid waste than using plastic bags.
- Whatever type of bag is used, the key to reducing its impacts is to reuse it as many times as possible and, where reuse for shopping is not practicable, other reuse options, e.g., to replace bin liners, are beneficial.
- The reuse of conventional HDPE and other lightweight carrier bags for shopping and/or as bin liners is pivotal to their environmental performance. Reuse as bin liners produces greater benefits than recycling of bags.
- Paper bags have a greater adverse impact than plastic bags for most of the environmental issues considered. Areas where paper bags score particularly badly include water consumption; acidification, which can have negative effects on human health, sensitive ecosystems, forest decline and lakes; and eutrophication of water bodies, which can lead to the growth of algae and the depletion of oxygen.
- Heavyweight, reusable plastic bags (so-called bags for life) are more sustainable than all types of lightweight plastic carrier bags if used four times or more.
- Paper bags are between 6 and 10 times heavier than lightweight plastic carrier bags and, consequently, require more transport with its associated costs. They also take up more room in a landfill if they are not recycled.
- Compared with lightweight HDPE bags and reusable LDPE bags, single-use paper bags perform worse across all environmental indicators (energy consumption, water consumption, climate change, acidification, air quality, eutrophication, waste and litter) except of risk of litter.
- A substantial shift from single-use disposable bags to more durable reusable bags would deliver an environmental gain over the full life cycle of the packaging. Less significant and consistent gains would be made by switching from HDPE to other single-

use bags, such as paper and biodegradable bags, with the potential gains in litter being offset by negative resource use outcomes.

- There are no significant differences in reusable bag environmental outcomes. Reusable heavy-duty plastic bags, which can combine low resource use, longevity and recycling, came out on top.
- The use of biodegradable bags would offer benefits in litter persistence but would not deliver significant resource use gains and would not be compatible with plastic bag recycling.
- Environmental gains from reusable bags are closely linked to the life expectancy of the bags, their weight-to-capacity ratio and their final destination – low litter, high recycle.
- Although paper and certain plastics may be biodegradable or compostable in specially designed industrial facilities, evidence indicates that this feature may be of little value in the effort to reduce waste. Research shows that in modern landfills paper does not degrade or break down at substantially faster than plastics. Because of the lack of water, light, oxygen and other important elements necessary for biodegradation to occur, nothing completely degrades in modern landfills.
- Although the risk of litter may be the same for plastic and paper bags, plastic bags have a greater potential for adverse environmental impact when not reused, recycled or sent to landfill, particularly within the marine environment.

## Discussion

The research reviewed here supports the view, which is counterintuitive to many, that paper bags have greater environmental impacts during their manufacture and use than plastic bags.

The key issue, however, is not whether to use paper or plastic, but how the efficiency of carrier bags can be maximised through ways to reduce, reuse and recycle them – in that order. By putting more items in fewer bags, avoiding double bagging, switching to durable bags and reusing and recycling disposable bags, significant reductions in material and non-renewable energy consumption, pollution, solid waste, greenhouse gas emissions and litter will occur.

This conclusion is shared by INCPEN, which considers that there is little difference in the environmental performance of different packaging systems. There are bigger differences in performance existing between the best and worst performers undertaking the same operations than between one type of packaging system and another.

Evidence published by the *Wall Street Journal* suggests that paper bags are, however, over three times more likely to be recycled than plastic bags (see <http://online.wsj.com/article/SB124473522987806581.html>).

It should also be noted that, when not sent to landfill or recycled, non-biodegradable plastic bags have a greater potential for adverse impact than paper bags owing to their greater persistence and visibility in the environment. Such impacts, typically excluded from LCA studies on the basis of being difficult to quantify, include the effects on marine organisms of the ingestion of plastic bags (see [www.marineconnection.org/archives/marine\\_impacts/plasticbag.htm](http://www.marineconnection.org/archives/marine_impacts/plasticbag.htm); [www.rspb.org.uk/media/releases/231021-plastic-bags-a-threat-to-marine-wildlife](http://www.rspb.org.uk/media/releases/231021-plastic-bags-a-threat-to-marine-wildlife); [http://news.nationalgeographic.com/news/2003/09/0902\\_030902\\_plasticbags.html](http://news.nationalgeographic.com/news/2003/09/0902_030902_plasticbags.html); [www.who.edu/science/b/people/kamaral/plasticsarticle.html](http://www.who.edu/science/b/people/kamaral/plasticsarticle.html); and [www.mcsuk.org/what\\_we\\_do/clean+seas+and+beaches/litter+campaigns/go+plastic+bag+free](http://www.mcsuk.org/what_we_do/clean+seas+and+beaches/litter+campaigns/go+plastic+bag+free)).

Yours sincerely,



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