BRIEFING NOTE

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LIFE CYCLE SUSTAINABILITY ASSESSMENT OF GROCERY CARRIER BAGS IN SOUTH AFRICA

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KEY FINDINGS

We compare 16 types of carrier bags in terms of environmental and socio-economic performance. Overall, reusable plastic bags (particularly the 70 micron HDPE bag) perform better than single-use bags, assuming that they are in fact reused as often as possible. The best single-use bag is the common 24 µm HDPE bag, provided that it has 100% (or at least 75%) recycled content. Biodegradable bags perform poorly, except on the plastic pollution indicator. Single-use bags perform best in terms of employment, particularly paper bags, followed by 100% recycled 24 µm HDPE bags.

INTRODUCTION

We conduct a Life Cycle Sustainability Assessment (LCSA) of 16 different types of grocery carrier bags in South Africa (Table 1). The goal is to compare the different bags in terms of environmental and socio-economic performance across the product life cycle. The intention is to provide objective, scientific evidence to policymakers, retailers and the public about the impacts of single-use plastic carrier bags; as compared to reusable, biodegradable/compostable, and paper alternatives. In short, we aim to answer the question of which type of bag is "best" in the South African context.

METHODOLOGY

The different carrier bags were assessed and compared in terms of both environmental and socio-economic indicators. This goes beyond current Life Cycle Assessment (LCA) studies, which focus only on environmental indicators.

Environmental indicators were based primarily on the ReCiPe 2016 impact assessment methodology; which comprises 18 "midpoint" indicators, and 3 "endpoint" indicators, which are calculated by aggregating and weighting the midpoint scores. In turn, an overall "single score" can be calculated, by aggregating across the endpoint indicators.

As with other impact assessment methodologies, ReCiPe 2016 excludes indicators relating to the impacts of plastic pollution. As such, given the global prominence of this issue, we develop a new indicator, namely persistence of plastic material in the environment. This is used as a proxy for impacts associated with plastic pollution.

We also add two key socio-economic indicators that are particularly relevant in the South African context; namely impacts on employment, and affordability to consumers.

Table 1: Carrier bags assessed in the LCSA study

<table>
<tr><th>Single-use / reusable</th><th>Type of material</th><th>Name</th><th>Description</th><th>Modelled % of recycled content</th></tr>
<tr><td rowspan="12">Single-use

(Assumed number of uses: 1)</td><td rowspan="6">Fossil-based plastic</td><td>HDPE_24_100</td><td>HDPE; with thickness of 24 microns (24 µm)</td><td>100%</td></tr>
<tr><td>HDPE_24_75</td><td>HDPE 24 µm</td><td>75%</td></tr>
<tr><td>HDPE_24_50</td><td>HDPE 24 µm</td><td>50%</td></tr>
<tr><td>HDPE_24_25</td><td>HDPE 24 µm</td><td>25%</td></tr>
<tr><td>HDPE_24_0</td><td>HDPE 24 µm</td><td>0%</td></tr>
<tr><td>LDPE</td><td>Low density polyethylene</td><td>0%</td></tr>
<tr><td>Bio-additive</td><td>HDPE_ECM</td><td>HDPE bags with ECM additive to aid degradability</td><td>0%</td></tr>
<tr><td rowspan="4">Biodegradable plastic</td><td>PBS+PBAT_ZA</td><td>PBS+PBAT, locally produced PBS and PBAT</td><td>0%</td></tr>
<tr><td>PBS+PBAT_IMP</td><td>PBS+PBAT, imported PBS and PBAT</td><td>0%</td></tr>
<tr><td>PBAT+Starch_ZA</td><td>PBAT+Starch, locally produced PBAT and maize</td><td>0%</td></tr>
<tr><td>PBAT+Starch_IMP</td><td>PBAT+Starch, imported PBAT+Starch</td><td>0%</td></tr>
<tr><td>Paper</td><td>Paper</td><td>Brown (Kraft) paper bags</td><td>54.8%</td></tr>
<tr><td rowspan="4">Reusable (Assumed number of uses: 52)</td><td rowspan="4">Fossil-based plastic</td><td>HDPE_70</td><td>HDPE bags with a thickness of 70 µm</td><td>100%</td></tr>
<tr><td>PP</td><td>Polypropylene bags</td><td>0%</td></tr>
<tr><td>Polyester_W</td><td>Woven fabric polyester</td><td>100% (rPET)</td></tr>
<tr><td>Polyester_NW</td><td>Non-woven (spun-bond and stitched) polyester</td><td>85% (rPET)</td></tr>
</table>

FUNCTIONAL UNIT AND KEY ASSUMPTIONS

Since some bags are reusable, while others are intended for single use, looking at the environmental and socio-economic performance 'per bag' is not meaningful. Instead, a common 'functional unit' needs to be defined, which allows all bags to be compared on an equal basis. The **functional unit** for this study was:

"Carrying one person's annual groceries (870.48 litres) from the supermarket to the home in South Africa".

The number of each type of bag required to fulfil this functional unit was determined on the basis of the volumetric capacity of each bag, as well as the assumed number of times that each type of bag would typically be reused (see Table 1).

Specifically, we assume that:

- bags that are intended for single use will only be used once each; such that a new bag is purchased for each shopping trip
- bags intended for reuse will be reused continuously over the course of the entire year (i.e., 52 times, assuming a weekly shopping trip)

RESULTS

Based on the above-mentioned assumptions, the environmental impact associated with each type of bag is illustrated in Figure 1. These results take into account the number of times each bag is assumed to be reused (as per Table 1), and therefore the number of bags required over the course of the year to fulfil annual grocery shopping requirements. Note that the results in Figure 1 are based on the ReCiPe 2016 single score, which aggregates across the various environmental indicators in the ReCiPe 2016 impact assessment methodology (i.e., the new indicators developed in this study; namely persistence, employment and affordability; are excluded).

The results indicate that the reusable, fossil-based plastic bags have a far lower environmental impact as compared to the single-use options (fossil-based or biodegradable), over the course of one year's shopping.

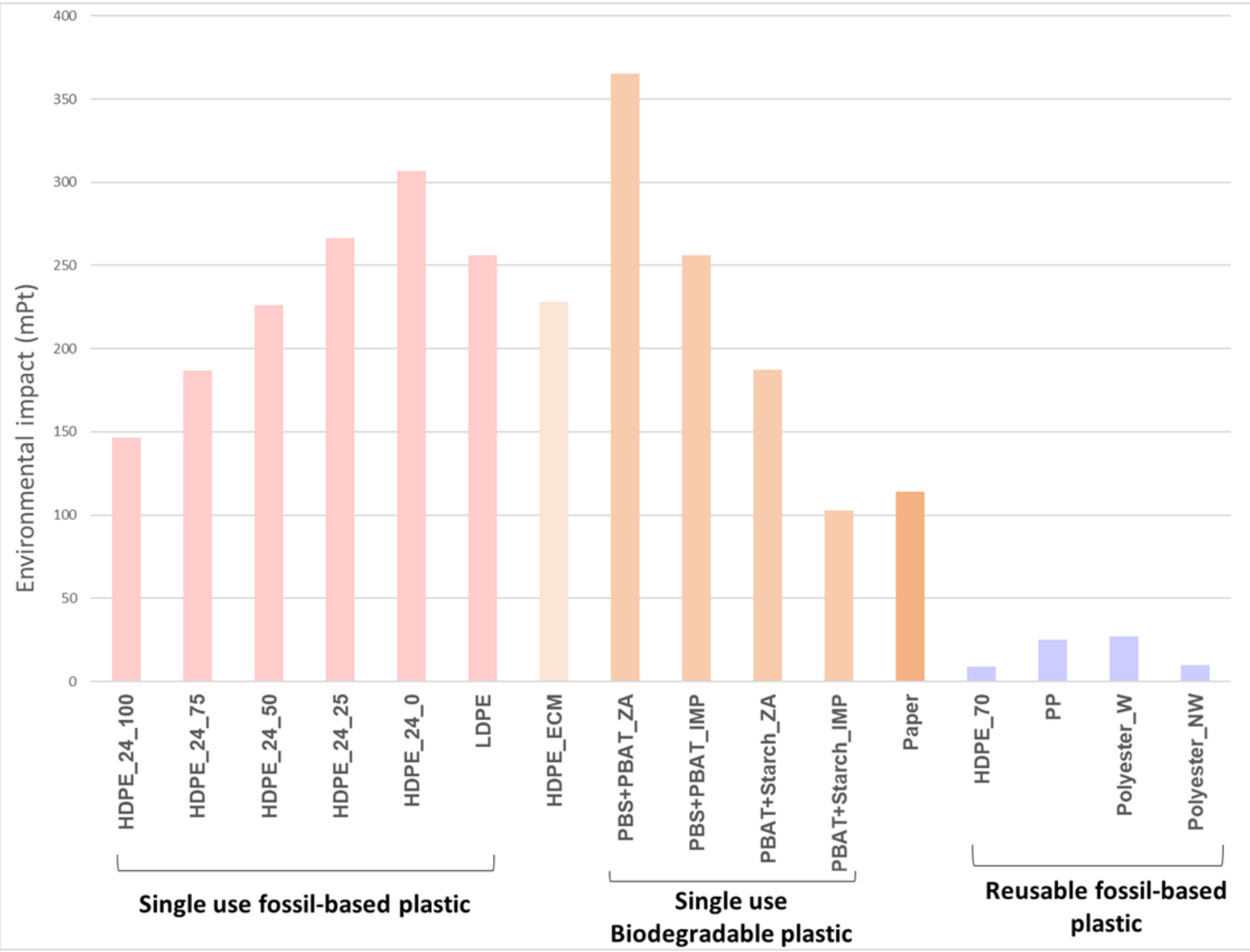

Figure 1: Environmental impact per bag type to fulfil one year's grocery shopping, based on ReCiPe 2016 single score (excluding persistence, employment and affordability). Based on assumption that single-use bags are used once each, and that reusable bags are used continuously to fulfil annual grocery shopping requirements.

Table 2: Overall ranking of bags across all environmental and socio-economic indicators (based on fulfilling annual shopping requirements; assuming that single-use bags are only used once each; and that reusable bags are reused continuously over the year). Overall ranking calculated based on equal weighting across indicators.

Rank	Bag type	Type of material	Single-use / reusable
1	HDPE_70	Fossil-based plastic	Reusable
2	Polyester_NW	Fossil-based plastic	Reusable
3	PP	Fossil-based plastic	Reusable
4	Polyester_W	Fossil-based plastic	Reusable
5	HDPE_24_100	Fossil-based plastic	Single-use
6	HDPE_24_75	Fossil-based plastic	Single-use
7	PBAT+Starch_IMP	Biodegradable plastic	Single-use
8	HDPE_24_50	Fossil-based plastic	Single-use
9	LDPE	Fossil-based plastic	Single-use
10	HDPE_ECM	Fossil-based with bio-additive	Single-use
11	HDPE_24_25	Fossil-based plastic	Single-use
12	PBAT+Starch_ZA	Biodegradable plastic	Single-use
13	HDPE_24_0	Fossil-based plastic	Single-use
14	Paper	Paper	Single-use
15	PBS+PBAT_IMP	Biodegradable plastic	Single-use
16	PBS+PBAT_ZA	Biodegradable plastic	Single-use

The overall ranking of bags (across all environmental and socio-economic indicators) is presented in Table 2. These rankings take into account both the ReCiPe 2016 indicators, as well as our new indicators (persistence, employment and affordability); and are based on an equal weighting across all indicators.

From Table 2 it can be seen that, over the course of a year, based on our assumptions regarding the number of times each bag is reused, the best performing bag overall is the reusable plastic HDPE 70 micron (µm) bag (HDPE_70), closely followed by the reusable non-woven polyester bag (Polyester_NW). Indeed, the four reusable bags (HDPE_70, Polyester_NW, PP and Polyester_W) occupy the top four positions in the rankings. The worst performing among the reusable bags (although still better than any of the single-use bags) is the woven polyester bag (Polyester_W).

Interestingly, the best performing among the single-use bags is the HDPE 24 µm bag with 100% recycled content (HDPE_24_100), which is currently the most common bag found in formal sector grocery stores in South Africa. It can also be seen that the higher the recycled content of the bags, the better the overall performance. The HDPE 24 µm bag with 100% recycled content (HDPE_24_100) achieves the highest ranking among the HDPE 24 µm bags, while the HDPE bags with lower recycled content rank progressively worse.

It is also evident from Table 2 that the worst performing bag overall is the biodegradable PBS+PBAT bag made using locally produced PBS and PBAT (PBS+PBAT_ZA).

Finally, it is notable that the top six bags are all made from conventional fossil-based plastics (HDPE, polyester and polypropylene). Of the seven worst performing bags, five are made from alternative types of materials (paper, biodegradable plastics, and the HDPE bag made with an ECM additive intended to aid biodegradation).

It should be borne in mind that the overall rankings in Table 2 are calculated assuming an equal weighting across all indicators. In principle, differential weighting could be applied to emphasise specific indicators of relevance to a particular decision making context (e.g. employment); or to highlight indicators where carrier bags make a disproportionately high contribution to the overall problem (e.g. persistence). It is therefore suggested that a set of weightings appropriate to the South African context be developed, through a multi-criteria decision analysis approach, incorporating government and other relevant stakeholders.

It is also important to note that these results are based on our assumption that single-use bags will only be used once each, and that reusable bags will be reused continuously over the course of a year to fulfil annual grocery shopping requirements. In reality, the reusable PP and polyester bags are likely to be able to last beyond one year; while it is also possible that, in their current design, the reusable HDPE_70 bags may not last for an entire year's worth of grocery shopping; with the handles noted as a potential weak point. Furthermore, bags that are intended for single use can in fact be reused to a certain extent.

As such, we conduct sensitivity analysis on these assumptions, as follows:

- Assuming that the HDPE_70 bag will only last for 6 months, or 3 months (as opposed to one year)
- Assuming that the PP and Polyester bags will last for 2 years, or 4 years (as opposed to one year)

- Assuming that the single-use bags will be used twice, or 4 times (as opposed to only once).

The results of the sensitivity analysis show that the overall rankings are robust to changes in these assumptions. Across all of these scenarios, the HDPE_70 and Polyester_NW bags retain the top two positions in the rankings. However, if we assume that the HDPE_70 bag will not last for an entire year, *or* that the Polyester_NW bag will last for longer than just one year; then these two bags trade places; with Polyester_NW becoming the top-ranked bag, and HDPE_70 falling to second.

The only time that these two bags fall out of the top two is if we assume that they will only be used a very small number of times; or, that single-use bags will be used many times over. Ignoring for now our assumptions from Table 1 regarding how many times each type of bag is reused, Table 3 provides an indication of the break-even point for each reusable bag, that is, the number of times that each reusable bag needs to be used in order to outperform the standard single-use HDPE 24 µm bag with 100% recycled content. Note that the break-even points in Table 3 are based on the ReCiPe 2016 aggregated single score, and therefore exclude the new indicators developed in this study.

Table 3: Number of uses required for reusable bags to break even with the reference bag (single-use HDPE 24 µm bag with 100% recycled content); based on environmental impacts (ReCiPe 2016 single score; excluding persistence, employment and affordability)

Bag type	Number of uses required to break even with the reference bag (HDPE_24_100)
HDPE_70	3
Polyester_NW	4
PP	9
Polyester_W	10

Finally, Table 4 presents the rankings for some specific indicators of interest; namely global warming, land use, water consumption, persistence (as a proxy for impacts associated with plastic pollution), employment, and affordability. Again, these results are based on the assumption that single-use bags will only be used once, and that reusable bags will be reused throughout the year to fulfil the functional unit.

Table 4: Ranking of bags on specific indicators of interest (listed from best to worst on each indicator). Based on fulfilling annual shopping requirements; assuming that single-use bags are only used once each; and that reusable bags are reused continuously over the year.

Rank	Global warming	Land use	Water use	Persistence (plastic pollution)	Employment	Affordability
1	HDPE_70	Polyester_NW	HDPE_70	PBAT+Starch_IMP	Paper	HDPE_70
2	Polyester_NW	HDPE_70	Polyester_NW	PBAT+Starch_ZA	HDPE_24_100	Polyester_NW
3	PP	Polyester_W	Polyester_W	PBS+PBAT_IMP	HDPE_24_75	PP
4	Polyester_W	PP	PP	PBS+PBAT_ZA	HDPE_24_50	LDPE
5	Paper	PBAT+Starch_IMP	HDPE_ 24_100	Paper	PBS+PBAT_ZA	HDPE_24_100
6	PBAT+Starch_IMP	PBAT+Starch_ZA	HDPE_ECM	HDPE_70	PBS+PBAT_IMP	HDPE_24_75
7	HDPE_ 24_100	HDPE_24_100	HDPE_ 24_75	Polyester _W	HDPE_24_25	HDPE_24_50
8	HDPE_ 24_75	HDPE_24_75	LDPE	Polyester _NW	HDPE_24_0	HDPE_24_25
9	HDPE_ 24_50	HDPE_ECM	HDPE_24_50	PP	LDPE	HDPE_24_0
10	HDPE_ECM	LDPE	HDPE_24_25	HDPE_ECM	PBAT+Starch_ZA	Polyester_W
11	PBAT+Starch_ZA	HDPE_24_50	HDPE_24_0	LDPE	HDPE_ECM	PBAT+Starch_ZA
12	LDPE	HDPE_24_25	Paper	HDPE_24_100	PBAT+Starch_IMP	PBAT+Starch_IMP
13	HDPE_24_25	HDPE_24_0	PBAT+Starch_IMP	HDPE_24_75	Polyester_NW	Paper
14	PBS+PBAT_IMP	PBS+PBAT_IMP	PBAT+Starch_ZA	HDPE_24_50	Polyester_W	PBS+PBAT_ZA
15	HDPE_24_0	PBS+PBAT_ZA	PBS+PBAT_ZA	HDPE_24_25	HDPE_70	PBS+PBAT_IMP
16	PBS+ PBAT_ ZA	Paper	PBS+PBAT_IMP	HDPE_24_0	PP	HDPE_ECM

The rankings for most environmental indicators (e.g. global warming, land use and water use in Table 4) are similar to the overall rankings presented in Table 2; with the four fossil-based plastic reusable bags occupying the top four positions. Single-use Paper bags perform particularly poorly in terms of land use, while the biodegradable plastic bags perform poorly in terms of water use.

By contrast, in terms of persistence (a proxy for the impacts associated with plastic pollution), the biodegradable bags occupy the top five positions, as expected. In particular, the biodegradable plastic bags (made from PBAT+Starch and PBS+PBAT) are the best performers, followed by Paper. These are followed by the reusable bags, which fare relatively well on this indicator under the assumption that they are reused many times throughout the year; which implies that only a relatively small amount of material is disposed of each year. However, it should be noted that, given the larger amount of material embedded in reusable bags (per bag), they would perform very poorly in terms of persistence if they are instead used only a small number of times before being discarded.

Interestingly, the HDPE_ECM bag, which is marketed as being biodegradable, fares relatively poorly on the persistence indicator (i.e., it does not biodegrade to the extent that is expected). This finding is consistent with the contested nature of its claimed biodegradability. Finally, as expected, the single-use fossil-based plastic bags perform worst in terms of persistence.

However, the results show that even biodegradable materials can persist in the environment when the rate of biodegradation is less than the rate of accumulation from continued disposal. This suggests that reduced consumption of bags through an emphasis on reuse should be a focus of intervention to reduce plastic pollution.

Turning to the socio-economic indicators, the rankings in terms of employment are the opposite of what is found for most of the environmental indicators. Based on our assumptions regarding the number of times each type of bag is used; the single-use bags are preferable from an employment perspective. This is because significantly more single-use bags would need to be produced per annum to fulfil annual grocery shopping requirements as compared to reusable bags; resulting in more jobs. In other words, if there was a switch away from producing single-use bags towards producing only reusable bags, a decrease in employment could be expected.

In particular, single-use Paper bags perform best from an employment perspective, with significantly more jobs involved in producing the number of Paper bags that would be required to fulfil annual shopping needs as compared to any of the plastic options. Interestingly, the second best bag from an employment perspective is the standard single-use HDPE 24 µm bag, specifically the variant with 100% recycled content; followed by the versions with 75% and 50% recycled content, respectively. This suggests that the current status quo bag does indeed perform relatively well from an employment point of view. It also indicates that the higher the recycled content, the better the performance in terms of employment, owing to the labour intensive nature of the recycling industry (collection, sorting etc.) in South Africa.

Finally, in terms of affordability, contrary to what may have been expected, the reusable bags generally perform better than the single-use bags, over the course of a year. Although reusable bags have higher upfront costs as compared to single-use bags (i.e., higher cost per bag), they begin to pay off the more often they are reused. Over the course of a year, assuming that single-use bags are only used once, and that reusable bags are reused continuously to fulfil annual grocery shopping requirements, the reusable bags are more cost-effective. While the upfront cost of the polyester and PP reusable bags in particular may be prohibitive for very low income consumers, the HDPE_70 reusable bag has a far lower upfront cost.

CONCLUSIONS AND RECOMMENDATIONS

Based on overall performance across all environmental and socio-economic indicators, and on our assumptions regarding the number of times each type of bag is reused; the best performing bags are the fossil-based plastic reusable bags (HDPE_70, Polyester_NW, PP and Polyester_W). In fact, the top six bags are all made from conventional fossil-based plastics (HDPE, polyester and polypropylene). Of the seven worst performing bags, five are made from alternative types of materials (paper, biodegradable plastics, and the HDPE bag made with an ECM additive intended to aid biodegradation). A sensitivity analysis indicates that these rankings are robust to changes in key assumptions.

In terms of the results for specific indicators; the rankings on most environmental indicators are similar to the overall ranking; with the four fossil-based plastic reusable bags generally occupying the top four positions. Single-use Paper bags perform particularly poorly in terms of land use, while the biodegradable plastic bags perform poorly in terms of water use. In terms of persistence, the biodegradable plastic bags (made from PBAT+Starch and PBS+PBAT) perform best, followed by Paper. The HDPE_ECM bag, which is marketed as being biodegradable, fares relatively poorly, as do the single-use fossil-based plastic bags.

In terms of socio-economic indicators, the ranking in terms of affordability is similar to the rankings on the environmental indicators; with the reusable bags generally performing better than the single-use bags, over the course of a year. Although reusable bags have higher upfront costs than single-use bags, they begin to pay off the more often they are reused.

Finally, the rankings for employment are the opposite of what is found for most of the environmental indicators. Specifically, based on annual shopping requirements, single-use bags are preferable to reusable bags from an employment perspective; as more bags need to be produced, resulting in more jobs. In particular, single-use Paper bags perform best from an employment perspective; followed by the standard single-use HDPE 24µm bags, particularly those with higher proportions of recycled content.

Returning to the overall rankings across all indicators (Table 2); assuming that single-use bags are only used once, and that reusable bags are reused continuously to fulfil annual grocery shopping requirements, the reusable HDPE 70 µm bag (HDPE_70) is the top-performing bag overall; closely followed by the reusable non-woven (spun-bond and stitched) polyester bag (Polyester_NW). Specific findings and recommendations regarding these two bags are as follows:

- The HDPE 70 µm bag (HDPE_70) is the top-performing bag overall, assuming an equivalent lifespan as the second-placed bag (Polyester_NW). However, in its current design, the HDPE_70 bag does not appear to be as durable as the other reusable bags (Polyester or Polypropylene). In particular, the handles may be a weak point, which could potentially limit the number of times this type of bag can be reused. Nevertheless, this limitation could potentially be overcome through improved design. In addition, the break-even analysis finds that the HDPE_70 bag only needs to be used three (or more) times to surpass the environmental performance of the single-use reference bag.

- The non-woven (spun-bond and stitched) polyester bag (Polyester_NW) is the second best performing bag overall, assuming an equivalent lifespan with the HDPE_70 bag. Assuming a longer lifespan as compared to HDPE_70, the Polyester_NW bag overtakes HDPE_70 as the top-ranked bag. Discussions with experts suggest that polyester bags are not currently recycled in South Africa. However, polyester can in principle be recycled through reheating and conversion back into polymer fibres for further reuse. The feasibility of this technology should therefore be investigated for South Africa; as recycling of these bags would further improve their performance (although not to the extent that it would overtake the HDPE_70 bag).

In general, the analysis shows that for all types of bags, the more times a bag is reused, the better its performance; particularly from an environmental (and affordability) perspective. The number of times a bag is reused is the single largest contributing factor to its environmental performance, across all types of bags. Doubling the amount of times a bag is used (e.g. using a bag twice instead of just once) results in a halving of its environmental impact.

As such, the general recommendation is that all bags should be reused for their primary purpose (to carry groceries) as many times as possible. Even bags intended for 'single use' should be reused as many times as possible. On the other hand, using a reusable bag only once is the worst possible outcome; since these bags have a higher material content as compared to single-use bags; and therefore a higher environmental impact (per bag) if they are only used once. As such, approaches to behavioural change to encourage reuse of bags (such as economic incentives, behavioural 'nudges', etc.) should be considered.

Only when primary reuse (as a carrier bag) is no longer possible, should bags be reused for a secondary purpose, e.g. as a bin liner (Danish EPA, 2018).

Finally, only when all options for primary and secondary reuse have been exhausted, should bags be recycled or composted (as appropriate). The analysis shows that increasing recycling rates does lead to some improvement in environmental performance; although not to the same extent as an increase in the number of times bags are reused. An increase in recycling rates from current rates to 60% leads to a 4% reduction in environmental impact, on average. In terms of recycled content, the HDPE 24 µm bag with 100% recycled content performs 52% better as compared to the 0% recycled HDPE bag. However, increasing the number of times bags are reused remains the single most effective way of improving their environmental performance.

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A copy of the full research report is available at: https://www.wasteroadmap.co.za

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