Environmental impacts of plastic bags, paper bags and cotton bags

MM 447 (Group 5)

(Bibhuti 19i170010 & Vishnu 17d110008)

Abstracts

The main function of carrier bags is to carry goods and the groceries. Hence we need some strength to the bags to hold certain quantities. There are different types of light weight carrier bags used in the market. All of them have some environmental impact. In this study we are going to see mostly used different types of carrier bags and their different types of impacts on the environment. We will also talk about the effects of these bags for sustainable development.

1 Introduction

We are polluting marine life, wild life or in general our environment because of littering, cutting the trees, etc due to the use of lightweight carrier bags. In the UK around 10 billion lightweight carrier bags were given away in 2008, which equates to approximately 10 bags a week per household. So these days we are generally talking about the impacts of carrier bags and the alternative of these bags. The debate arises because of public, media and legislative pressure to reduce the environmental impacts of these bags.

In general Life Cycle Assessment (LCA) is a standard method for comparing the environmental impacts of providing, using and disposing of a product. Or in an indirect way LCA identifies the materials, energy uses, emissions, waste flow of a product, etc. Cotton and paper bags may be worse than plastic bags.

1.1 Different types of carrier bags

Super markets generally used different types of high densities and low densities polyethylene bags (HDPE & LDPE), biopolymer bags, paper bags, non-woven polypropylene (PP) and cotton bags. Who’s weight and volume varies in the following range

Bags type	Picture	Weight (g)	Volumetric capacity (L)
Conventional HDPE		7.5 – 12.6	17.9 – 21.8
Heavy duty LDPE bag		27.5 – 42.5	19.1 – 23.9
Biopolymer		15.8	18.3
Non-woven PP		107.6 – 124.1	17.7 – 21.8
Paper bags		55.2	20.1
Cotton bags		78.7 – 229.1	17 – 33.4

These are the bags which are used in supermarkets. The data is taken from UK supermarket analysis.

1.2 Plastic

This type of polymer mainly possesses issues like littering, carbon imbalance, etc. We have different ways for handling the plastic…

1st :- Landfilling

2nd :- Incineration

3rd :- Gasification

4th :- Dissolution

5th :- Mechanical

6th :- Pyrolysis

Each one has their own merits and demerits like landfilling has environmental issues, incineration has environment and scaling issues, and other than this other process needs clean feed. Similarly

Gasification - Operational issues and Environment

Mechanical Recycling- Inability to handle end-of life plastic

Solvent Dissolution - Energy and Material intensive

Pyrolysis - Operational issues and Scale-up

In this study we have compared different environmental impacts of the different types of bags with respect to plastic bags…

For our analysis we have taken the bags having volume and weight per bags are as follows

Bag type	Volume per bag (litres)	Weight per bag (g)
Conventional high-density polyethylene (HDPE) bag	19.1	8.12
High-density polyethylene (HDPE) bag with a prodegradant additive	19.1	8.27
Starch-polyester blend bag	19.1	16.49
Paper bag	20.1	55.20
Low-density polyethylene (LDPE) bag	21.52	34.94
Non-woven polypropylene (PP) bag	19.75	115.83
Cotton bag	28.65	183.11

2 Impact Assessment

The first section of this impact assessment we used for each carrier bag is the 2007 IPCC (Intergovernmental Panel on Climate Change) reflecting the Global Warming Potential (GWP) or carbon footprint. In this study, the impacts of the GWP lifecycles are analysed in depth which requires secondary reuse as bin liner but lacks (i.e. reuse of lightweight bags). The amount of times each heavy duty bag is to be used, for the GWP to fall below the baseline level for the standard HDPE bag. Besides the secondary reuse of traditional HDPE carrier bags, No accurate data was available on primary reuse of bags. This method only illustrates the amount of times each bag is supposed to be used in order to reduce the GWP below that of the traditional carrier bag. Real reuse depends on use, bag power and lifespan. Therefore, some reuse figures are unrealistic.

The second section of the impact calculation is based on the hypothetical usage of stage one measured for individual bags using CML-baseline. Most bar diagrams display the contribution of a lifecycle stage to an impact category for every type of carrier bag. These lifecycle stages include:

- **The extraction/production of raw materials** (HDPE, LDPE, paper, cotton, etc)

- **The production processes** (Usage of energy during carriage bag production)

- **Transport** (Shift raw materials to the plant and finished carrier bag to the supermarket)

- **End-of-life** (Includes collection, landfill and incineration)

- **Avoided products and recycling** (The prevention by secondary reuse or recycle of virgin products)

Positive values means harmful consequences. Negative values means from the life cycle processes of 'recycling & product avoidance' are positive and minimise the total effect by the amount shown

2.1 Global warming potential (GWP)

The GWP for each lifecycle step of each carrier bag (apart from primary reuse) is shown below.

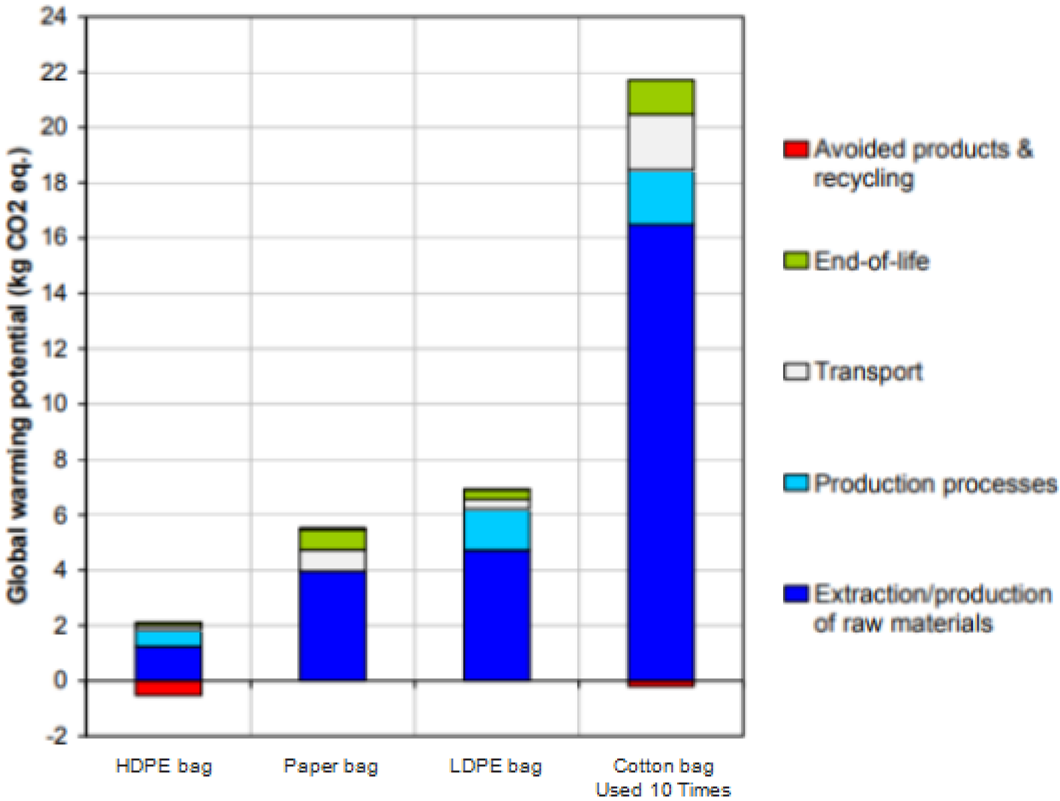


Figure: Lifecycle impacts on the global warming potential of each carrier bag (not including primary reuse).

GWP of all carrier bags examined is dominated by collecting and manufacturing raw material. This effect is usually attributed to the production of 64 percent of the HDPE bag impact from extracting and processing HDPE from the most prevalent material.

The total global warming effect of packaging products for each carrier bag usually amounts to between 0.4 and 4%. The GWP of grid power used for the manufacturing of carrier bags is 38% for HDPE bags, Even if this proportion was determined by the effect in the country of origin of other lifecycle, such as the extraction and processing of raw materials and the energy mix: the HDPE bag is mostly produced in asia, which relies heavily on burning coal power.

The effect of transport on the overall volume of GWP is between 0.8% to 14% and is strongly contingent on the distance of road transport.

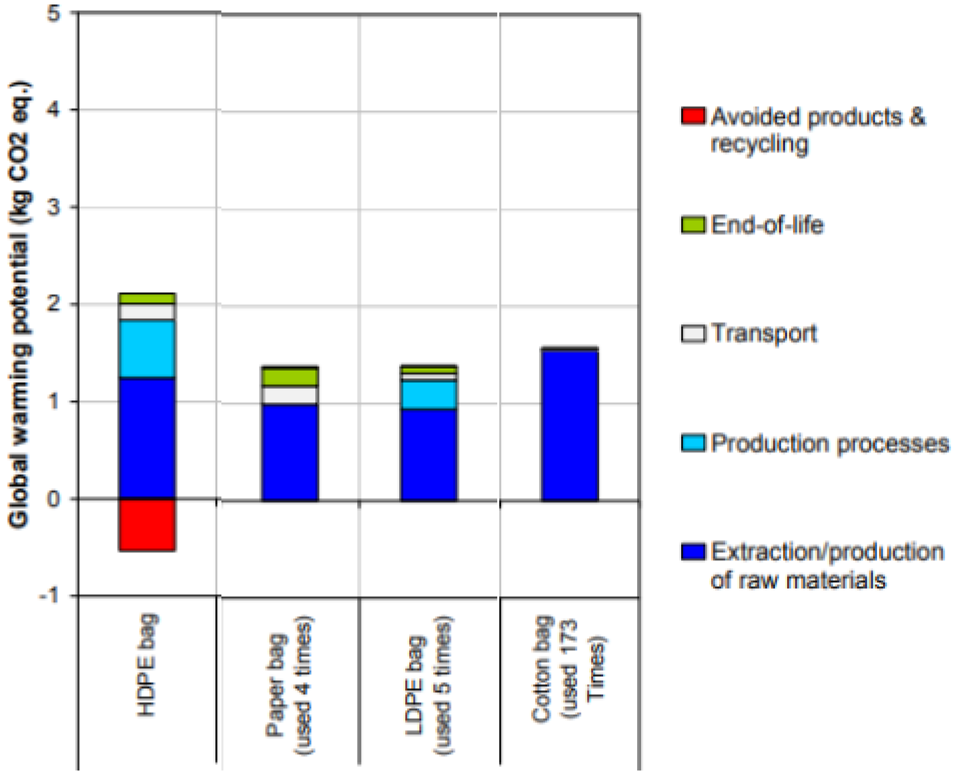


Figure: The global warming potential impacts of each type of carrier bag assuming each is reused to outperform a HDPE bag

The end-of-life impacts on the gross GWP range of all bags range from 0.2% to 33%. The end-of-life of plastic bags are usually between 5% and 7%, and the GWP is dominated by plastic incineration. Nevertheless a deposit which contributes over 18% and 29% to the overall impact is dominating the end-of-life of the paper bag and of the cotton bag. Incineration lowers the GWP of the paper bag by 5 per cent because of the energy from waste incineration, to counteract the direct impacts of global warming.

In the significant decrease produced in both statistics by the prevented life cycle of items, the impact of the secondary reuse of 40.3 percent of light bags is shown. This reuse lowers the impact by 32% for the HDPE bags.

2.2 Other Impact Categories

In order to quantify additional environmental impacts for each carrier bag, the CML 2 baseline 2000 technique was applied. The findings of each of the following parts display the 8 types of effect considered and the above listed GWP results. These findings are shown in bar charts which display the contribution to each effect of each life cycle point. In certain cases the lifecycle stages of 'end of life' and 'recycle & prevent goods' also reduce their effects. These are thus seen in the bar charts as negative percentages.

2.2.1 HDPE carrier bag

Table below shows the outcome of the impact assessment for conventional HDPE bags and figure below shows relative contributions throughout each point of the life cycle.

Table: Environmental impact of the HDPE bag

Method	Impact category	Unit	Total
IPCC 2007	Global warming potential	kg CO2 eq	1.578
CML 2 baseline	Abiotic depletion	g Sb eq	16.227
	Acidification	g SO2 eq	11.399
	Eutrophication	g PO4--- eq	0.775
	Human toxicity	kg 1,4-DB eq	0.211
	Fresh water aquatic ecotox.	g 1,4-DB eq	66.880
	Marine aquatic ecotoxicity	kg 1,4-DB eq	126.475
	Terrestrial ecotoxicity	g 1,4-DB eq	1.690
	Photochemical oxidation	g C2H4	0.531

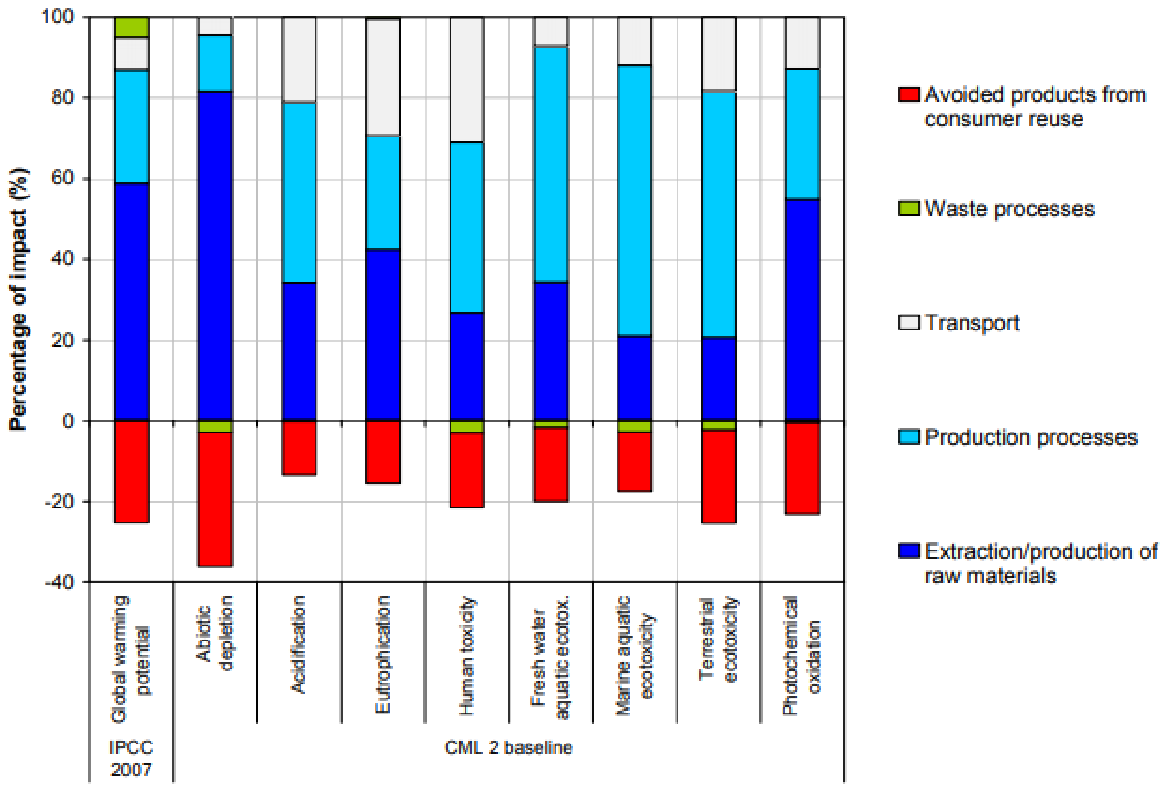


Figure: The relative effect of HDPE bags on the environment of different life cycle stages

The manufacturing method has the highest life-cycle effect in five of the eight groups, including acidification, human, marine and land toxicity. This results from the electricity used made from grid and the removal of coal ash burnings. However, IEA statistics indicate that some countries manufacturing bags, including Malaysia, have a lower dependency on coal, so that bags manufactured in those areas will have a smaller effect. The effects of the development, operation and usage of the power supply network also has an effect on the terrestrial ecotoxicity of the HDPE bag.

Material extraction and manufacturing have the greatest effect and control in the other three of the eight areas of impact. In regards to the toxicity and ecotoxicity, the use of titanium dioxide, since it is just 2% of the bags' weight, has a substantial effect on the physical life cycle. For example, during the extraction and manufacturing of titanium dioxide, the release of vanadium contributes more than 19% to the environment of the HDPE bags. The use of titanium dioxide only in opaque bags is significant, which means that transparent bags of the same weight have less effect in those categories.

A major part of the eutrophication and human pollution impacts is based on the distance and mode of transport of the HDPE bags due to the emission of nitrogen oxides and polycyclic aromatic hydrocarbons respectively from shipping. Owing to the comparatively short transport distances (100 km to 200 km), transport by road of the raw materials to the carrier bag maker and the importer to the supermarkets has little effect on results. The total influence of the end-of-life stage in 5 of the eight groups is decreased, primarily because the incineration impact is outweighed by the consequences prevented by power generation from waste to energy.

The reuse of HDPE bags as bin liners lowers the environmental effect by 13% to 33%. In categories where raw material usage dominates the effect reduction from avoided bin liners is highest. However, the advantage of this avoided substance is attributable to the avoided extrusion process in certain places like the human, marine and terrestrial ecotoxicity rather than the avoided use of energy.

2.2.2 Paper carrier bag

In the table below and in the figure, the findings of the CML 2 baseline paper bag impact assessment are shown. The results in the table include no reuse and the hypothetical four uses calculated in the above mentioned section. Some retailers use paper carriers in the world or are used as bin liners, which are not as durable and readily divisible or tearable as HDPE containers. Although paper bags have been introduced in many parts of the world, still there is no data that shows the reuse of it.

Table: The environmental impact of the paper bag

Assessment method	Impact category	Unit	Total (no reuse)	Total (used 4 times)
IPCC 2007	**Global warming potential**	kg CO2 eq	5.523	1.381
CML 2 baseline	**Abiotic depletion**	g Sb eq	26.697	6.674
	Acidification	g SO2 eq	37.470	9.367
	Eutrophication	g PO4--- eq	5.039	1.260
	Human toxicity	kg 1,4-DB eq	3.247	0.812
	Fresh water aquatic ecotox.	g 1,4-DB eq	150.204	37.551
	Marine aquatic ecotoxicity	kg 1,4-DB eq	244.657	61.164
	Terrestrial ecotoxicity	g 1,4-DB eq	24.719	6.180
	Photochemical oxidation	g C2H4	1.955	0.489

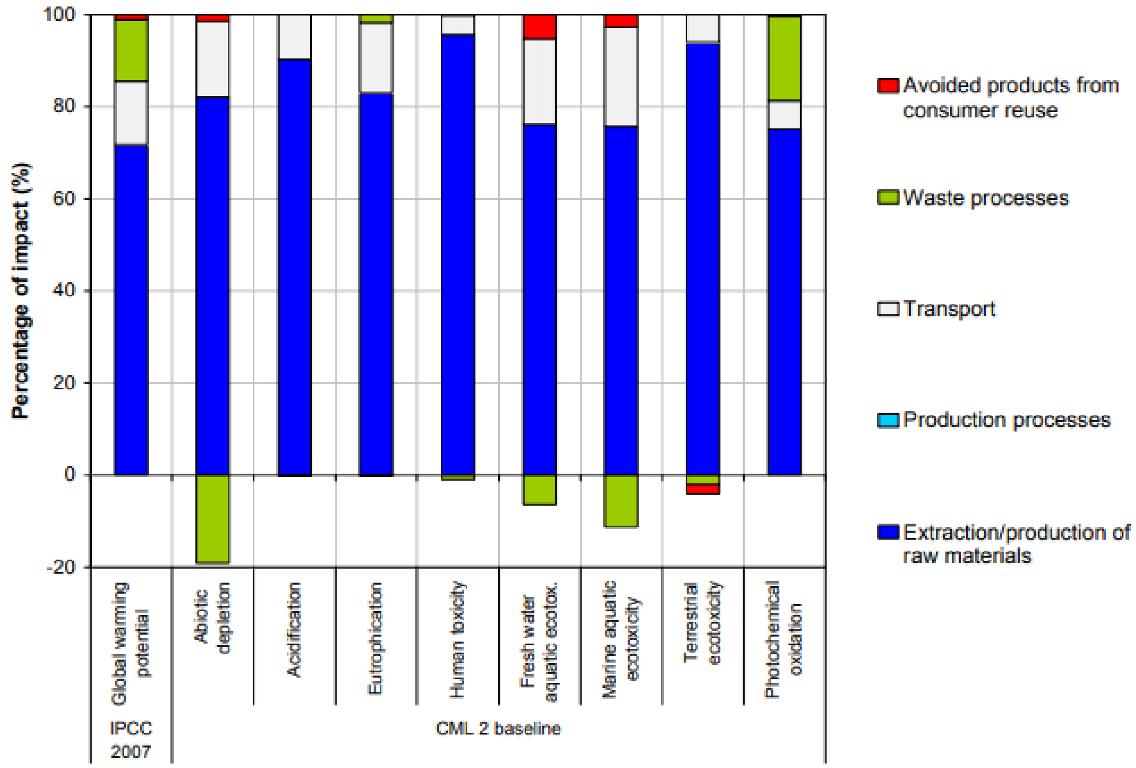


Figure: The life-cycle impacts of the paper bag

The life-cycle impacts of the paper bag are controlled by the resource extraction and development phases. As the data could not be isolated, this cumulative stage contributes over 70 per cent of the effect in all eight groups. Due to the aggregate nature of the data, processes or materials contributing to such impacts are difficult to identify. However, we analysed the production of the paper and found a significant contribution to all the impacts of the energy needed from grid electricity. Eutrophication and the ecotoxicity of fresh water are also affected by the dumping of ash from paper production. Palm oil production for use in paper production affects land-based ecotoxicity. While bags are manufactured all over the world, most impact categories still notice the distribution of the bags from the bag manufacturers to the supermarkets through the importer. The impacts on the acidification, eutrophication, terrain and photochemical oxidation through road transport pollution and on the impact of diesel oil production on abiotic loss, human toxicity and marine ecotoxicity.

In certain cases, the recycle and prevented product process often causes a net burden (as opposed to light weight plastic bags), since the paper bag is not re-used as a bin liner, so the recycling phase is just at the end of its lifespan. The effect of the recycling process in this situation is greater than the avoided manufacturing of cards, which results in a net improvement. In abiotic degradation and marine ecotoxicity, an effect of reduction of end-of-life production is observed as power is not produced by energy from waste incineration. However, 18% of photochemical oxidation is added by waste production because of its effect on this category.

2.2.3 LDPE carrier bag

The LDPE bag's environmental impacts are seen in the table below and each lifecycle process applies to each impact mentioned in the figure below. The LDPE transport bag system contributes at least 65% to 5 of the seven categories of raw material production. Polyethylene production is mainly responsible for the effects of abiotic degradation, GWP and photochemical oxidation. Titanium dioxide production is therefore a significant factor in human toxicity and marine ecotoxicity.

Table: The environmental impact of the LDPE bag

Assessment method	Impact category	Unit	Total (no reuse)	Total (used 5 times)
IPCC 2007	**Global warming potential**	kg CO2 eq	6.924	1.385
CML 2 baseline	**Abiotic depletion**	g Sb eq	82.711	16.542
	Acidification	g SO2 eq	29.340	5.868
	Eutrophication	g PO4--- eq	2.576	0.515
	Human toxicity	kg 1,4-DB eq	0.701	0.140
	Fresh water aquatic ecotox.	g 1,4-DB eq	186.726	37.345
	Marine aquatic ecotoxicity	kg 1,4-DB eq	311.810	62.362
	Terrestrial ecotoxicity	g 1,4-DB eq	7.323	1.465
	Photochemical oxidation	g C2H4	1.391	0.278

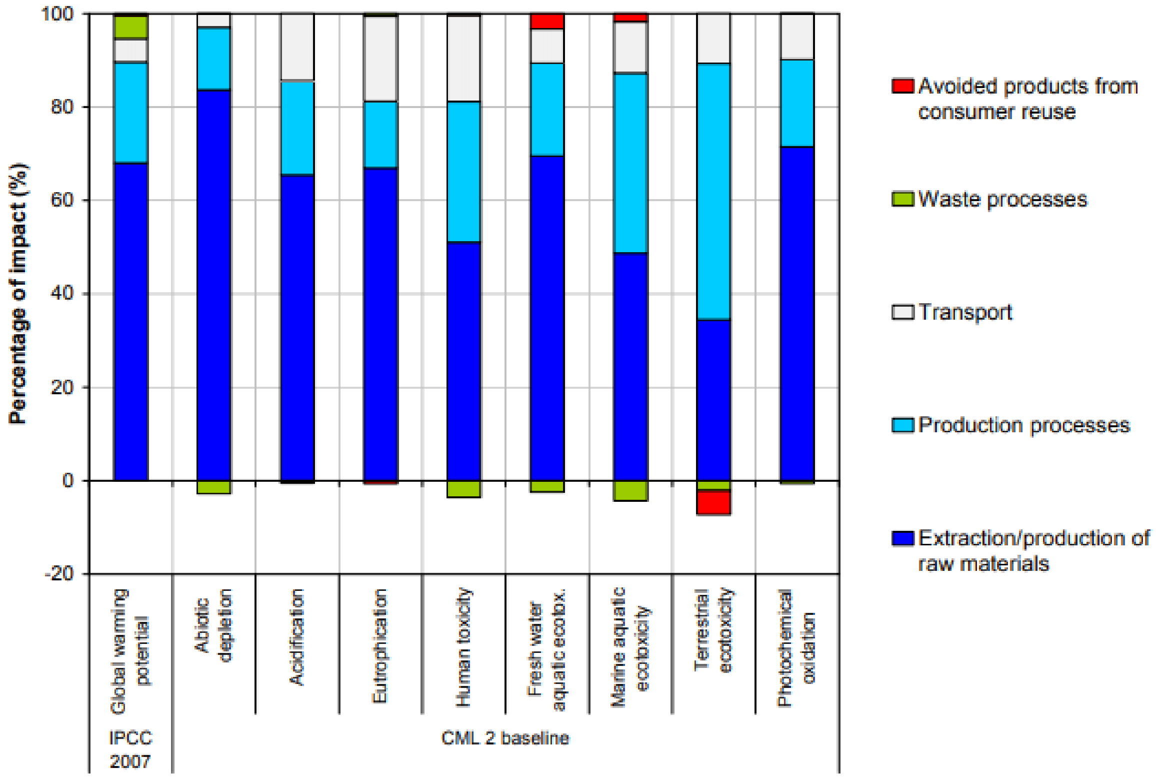


Figure: The lifecycle impacts of the LDPE bag

The burdens from the conversion of LDPE pellets into carrier bags are an important factor in several impact categories. In the case of terrestrial ecotoxicity this impact is due to the effects of the electricity transmission network, but for most impacts it is due to emissions and waste ash produced by coal fired power stations in the production locations.

The transport and distribution of carrier bags from maker to supermarket contribute significantly to the effects of human poisoning, acidification and eutrophication. For eutrophication, transport influence is shared equally between land and sea transportation because of nitrogen oxides pollution from road vehicles; for the most part, however, transport contributes primarily through marine transport due to nitrogen oxides emissions.

The recycling and product evasion process includes the recycling of primary packs like cardboard. It decreases the terrestrial ecotoxicity network and has a minor effect on marine ecotoxicity, including the paper bag. The results of end-of-life processing are very close to the manner in which the HDPE bag is modelled.

2.2.4 Cotton carrier bag

The effects of cotton bags on the atmosphere (used 173 times) shown in the table below. The findings of the cotton bag category indicate that extraction and processing of materials makes up 98% of the categories of effects. This contribution is due in part to the presumption of woven cotton textiles as the raw material. The energy required to turn cotton into cotton yarn is a key contributor to the degradation, acidification, human toxicity, freshwater and sea ecotoxicity and photochemical oxidation of abiotic materials. The key source of use and manufacturing of fertiliser is the cultivation of cotton for eutrophication. Cultivation of cotton and resources during cultivation of cotton lead to terrestrial ecotoxicity nearly equal.

Table: The environmental impact of the cotton bag

Assessment method	Impact category	Unit	Total (no reuse)	Total (used 173 times)
IPCC 2007	**Global warming potential**	kg CO2 eq	271.533	1.570
CML 2 baseline	**Abiotic depletion**	g Sb eq	1519.838	8.785
	Acidification	g SO2 eq	2787.681	16.114
	Eutrophication	g PO4--- eq	304.486	1.760
	Human toxicity	kg 1,4-DB eq	66.254	0.383
	Fresh water aquatic ecotox.	g 1,4-DB eq	23477.073	135.706
	Marine aquatic ecotoxicity	kg 1,4-DB eq	44716.601	258.477
	Terrestrial ecotoxicity	g 1,4-DB eq	3208.855	18.548
	Photochemical oxidation	g C2H4	95.114	0.550

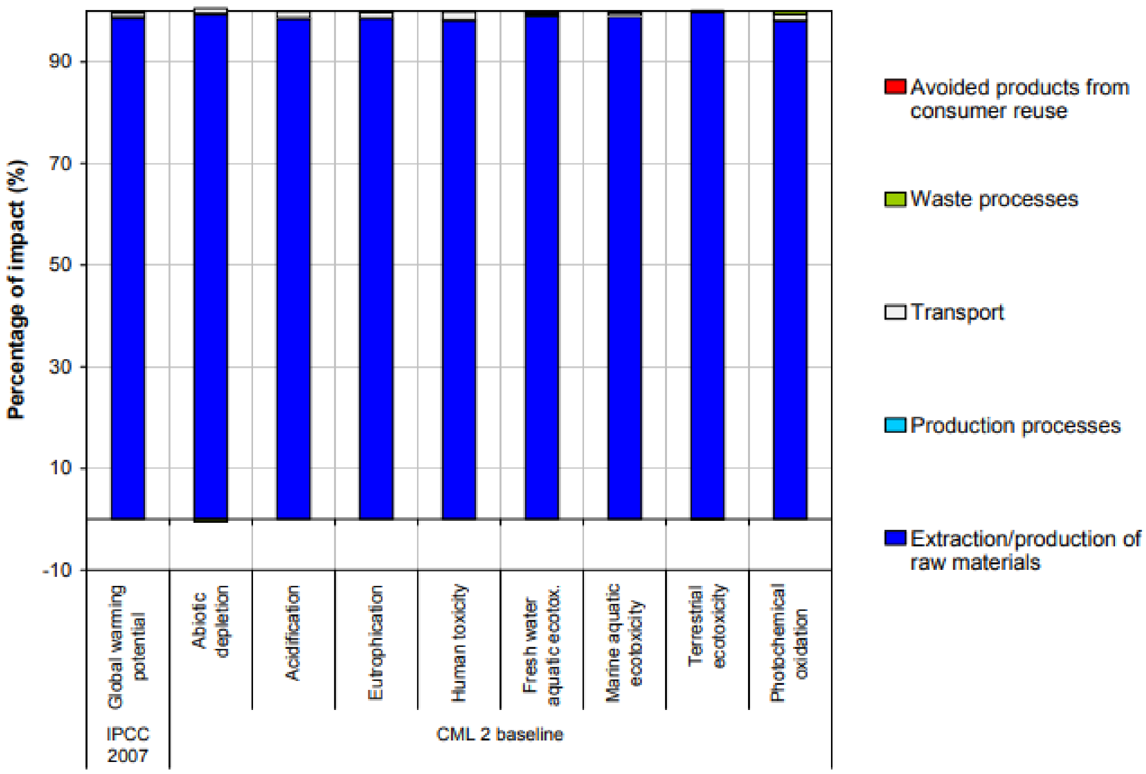
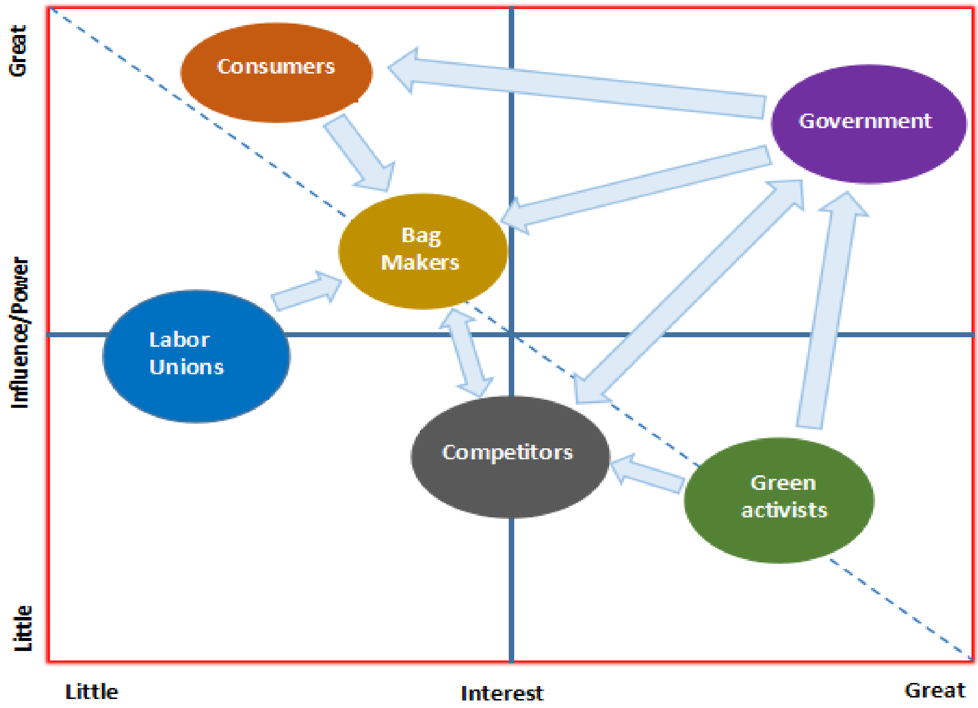


Figure: The lifecycle impacts of the cotton bag

3 Stake Holders



Governments - National, State, Local governments, it influences consumers to use and producers to produce recyclable bags and degrade them properly, if required passes law to force consumers to use certain types of bag only, hence producer will then make those bags only.

Bag Makers and suppliers - production and supply of bags to consumers as per the needs or according to rules.

Raw material producers/companies - production and supply of raw materials to bag making companies, according to their needs.

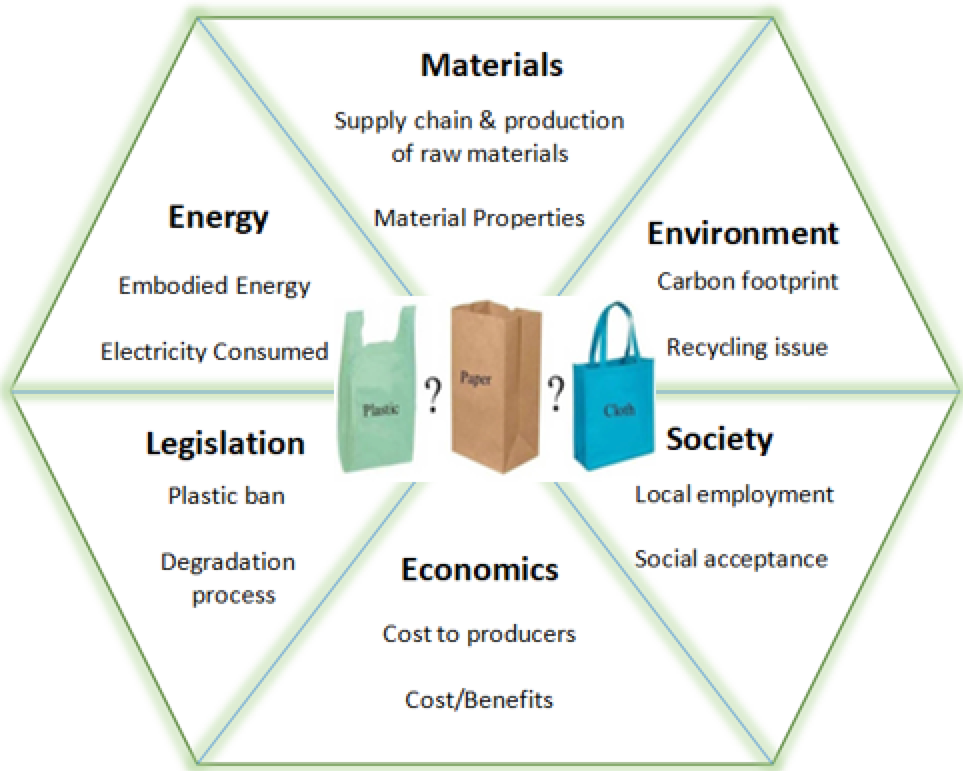
Labor Unions - to produce bags in the bag making factories

Competitors - Jute, Leather, nylon bag producers will influence the consumers to use their bags and hence there will be competition whose bag is better to use.

Green Activists - They will influence the government to pass laws for environmentally friendly bags and competitors to produce them.

Consumers - They will use the bags as per their requirements and the rules made by the government.

4 Factual Information



Materials - supply chain management and production of raw materials like plastic, cotton, paper, Titanium Oxide, etc. Titanium Oxide is used in plastics to make the bags transparent. For production of each type of bag, the companies need the raw material, so first the raw material is needed to be produced. Also the materials used in making the bags changes the properties of the bag.

Energy - Embodied energy is the sum of all non-renewable energy used to produce the final product. Instead of electricity used in the final stage to produce bags can be changed to renewable sources like solar or wind power.

Legislation - Rules made by governments for the consumption of products like plastic ban in Maharashtra.

5 Life cycle assessment (LCA)

LCA mainly concern on

1. The identification of the best disposal option for each carrier bag type within the identified end-of-life options - For each type of carrier bag and impact category at a time, we examined the characterized results for each of the end-of-life scenarios.

2. The identification of the multiple-use carrier bag alternative with the best environmental performance for each of the investigated impact categories - For each impact category, we identified the carrier bag alternative and the end-of-life scenario that provides the best environmental performance, as well as whether the identified environmental performance was significantly better than the one provided by the other carrier bag alternatives.
3. The identification of the number of times each multiple-use bag would need to be reused to lower the environmental impacts connected to its production and in comparison to other carrier bag alternatives, based on different reuse and disposal options.

This table showing different impacts and the reduction in the impact if you are using it multiple times (x)

Impact categories	HDPE bag	LDPE bag			Paper bag	Bio-degradable bag
		Used 2x	Used 4x	Used 20x		
Consumption of non-renewable energy sources	1	1.4	0.7	0.1	1.1	0.9
Consumption of water	1	1.3	0.6	0.1	4	1
Emission of greenhouse gases	1	1.3	0.6	0.1	3.3	1.5
Atmospheric acidification	1	1.5	0.7	0.1	1.9	1.8
Formation of photochemical oxidants	1	0.7	0.3	0.1	1.3	0.5
Eutrophication of water	1	1.4	0.7	0.1	14	12
Production of solid waste	1	1.4	0.7	0.1	2.7	1.1
Risk of littering	High	Average to low			Low	Average to low

This table is showing, bags having different types of littering effect and the primary energy used as well as the amount of greenhouse gases

Bag type	Material consumption (kg)	Litter (g)	Litter (m^2)	Litter (m^2/y)	Greenhouse (CO_2 eqv.)	Primary energy use (MJ)
HDPE, singlet	3.12	15.6	0.144	0.72	6.08	210
50% recycled HDPE, singlet	3.12	15.6	0.144	0.72	4.79	117
Boutique LDPE (single use)	11.77	58.8	0.195	0.975	29.8	957
Reusable LDPE	0.96	4.8	0.0121	0.0603	2.43	78
Calico	1.14	5.7	0.0041	0.0819	2.52	160
Woven HDPE swag	0.22	1.1	0.00148	0.00743	0.628	18.6
PP fibre 'Green Bag'	0.48	2.4	0.00187	0.00934	1.96	46.3
Kraft paper – handled	22.15	111	0.156	0.078	11.8	721
Solid PP 'Smart Box'	0.42	NA	NA	NA	1.1	38.8
Biodegradable – starch based (Mater-Bi)	6.5	32.5	0.156	0.078	6.61*	61.3

* Assumed to break down into carbon dioxide

And in this table, the amount of material used and the abiotic depletion and other impacts of different types of bags are mentioned.

Bag type	Material use (kg)	Greenhouse gases (kg CO_2 eq.)	Abiotic depletion (kg Sb eq.)	Eutrophication (kg PO_4^{3-} eq.)	Litter marine biodiversity (kg*yr)	Litter aeshetics (m^2*yr)
Starch-PBS/A	3.12	2.5	0.00487	0.00273	4.26E-05	0.078
Starch-PBAT	3.12	2.88	0.023	0.00406	4.26E-05	0.078
Starch-polyester	4.21	4.96	0.0409	0.00494	5.75E-05	0.078
Starch-PE	3.12	4.74	0.0694	0.00258	0.0078	0.078
HDPE & additive	3.12	6.31	0.101	0.00236	0.0039	0.078
PLA	4.212	16.7	0.0776	0.00911	5.75E-05	0.078
Lightweight HDPE	3.12	6.13	0.102	0.00246	0.0078	0.312
Kraft paper	22.152	30.2	0.285	0.0266	0.000302	0.078
PP fibre	0.209	1.95	0.023	0.00126	0.000241	0.00187
Woven HDPE	0.216	0.216	0.00934	0.000231	0.000107	0.00148
Calico	1.141	6.42	0.0177	0.00795	3.09E-06	0.00164
LDPE	1.04	2.76	0.0422	0.00114	0.00257	0.00746

6 Discussion and Conclusion:

- Goal of this study was to investigate and compare the environmental impact of carrier bags based on life cycle assessment (LCA).
- Environmental impacts of each type are significantly affected by the number of times a carrier bag is used.

- The life-cycle impact of all the bags is dominated by raw material extraction and the production of the carrier bag.
- The assessment shows that durable carrier bags have to be reused several times to have a lower global warming potential than the HDPE carrier bags. Whether this reuse is achieved depends both on the physical properties of the bag and consumer behaviour.

6.1 Conventional HDPE bags

The conventional HDPE bag had the lowest environmental impacts of all the impact categories. The bag performed well because it was the lightest bag considered. The lifecycle impact of the bag was dictated by raw material extraction and bag production, with the use of Chinese grid electricity significantly affecting the acidification and ecotoxicity of the bag.

6.2 LDPE Bags

The LDPE bag has to be used five times to reduce its GWP to below that of the conventional HPDE bag. When used five times, its impacts were lower in all categories. The impact was also substantially lower than the HDPE bag in terms of acidification, aquatic ecotoxicity and photochemical oxidation due to lower shipping distances and the use of grid electricity which is less reliant on coal.

6.3 Paper bags

The paper bag has to be used four or more times to reduce its global warming potential to below that of the conventional HDPE bag, but was significantly worse than the conventional HDPE bag for human toxicity and terrestrial ecotoxicity due to the effect of paper production. However, it is unlikely the paper bag can be regularly reused the required number of times due to its low durability.

6.4 Cotton bags

The cotton bag has a greater impact than the conventional HDPE bag in most of the impact categories even when used 173 times (i.e. the number of uses required to reduce the GWP of the cotton bag to that of the conventional HDPE bag with average secondary reuse). The impact was considerably larger in categories such as acidification and aquatic & terrestrial ecotoxicity due to the energy used to produce cotton yarn and the fertilisers used during the growth of the cotton.

6.5 To achieve sustainability:

- The bags should be used as many times as much possible to reduce the impact of it on the environment.
- Use of renewable energy resources for the extraction, production and transportation of carrier bags. (for eg. use of solar, wind, tidal, etc sources of energy to produce electricity which can be used to power the machines)

6.5.1 Three R’s

3 R stands for reuse, recycle and reduce the source. Mainly plastic bags are recycled at large scale. On the basis of recycling process, recycling are of four types

- Primary recycling
  - No change in physical or chemical properties
  - Segregate, sort and make pellets
- Secondary recycling
  - Properties of re-used material changes
  - Mechanical recycling
- Tertiary recycling
  - Different products formed
  - Chemical or fuel synthesis
- Quaternary recycling
  - Destruction
  - Incineration

Around 65 % of the plastic bags are recycled in China (exported from the UK). Recycling of plastic generates emissions but can be converted into different types of usable materials. Otherwise we had another option that uses a suitable additive for making plastic biodegradable. It will be another way of making our environment clean. This needs lots of study.

Once we start reusing the bags then we will observe reduction in resource consumption. This is another simple way of making our environment clean. We should reuse each and everything as possible as we can.

6.5.2 Three P’s

3 P stands for People, Planet and Prosperity. To achieve sustainable development we need to create a balance between the 3 Ps.

Planet - littering is one of the biggest issues, littering causes harsh effects on biodiversity especially to marine life and animals. We can reduce this by properly applying 3R’s.

People - Production, degradation, etc; each step requires human need to carry it out, therefore it creates sustainable employment & earning for local people.

Prosperity - End-of-life process adds additional costing. Paper bags are the cheapest followed by plastic bags and Cotton bags are the expensive ones.

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