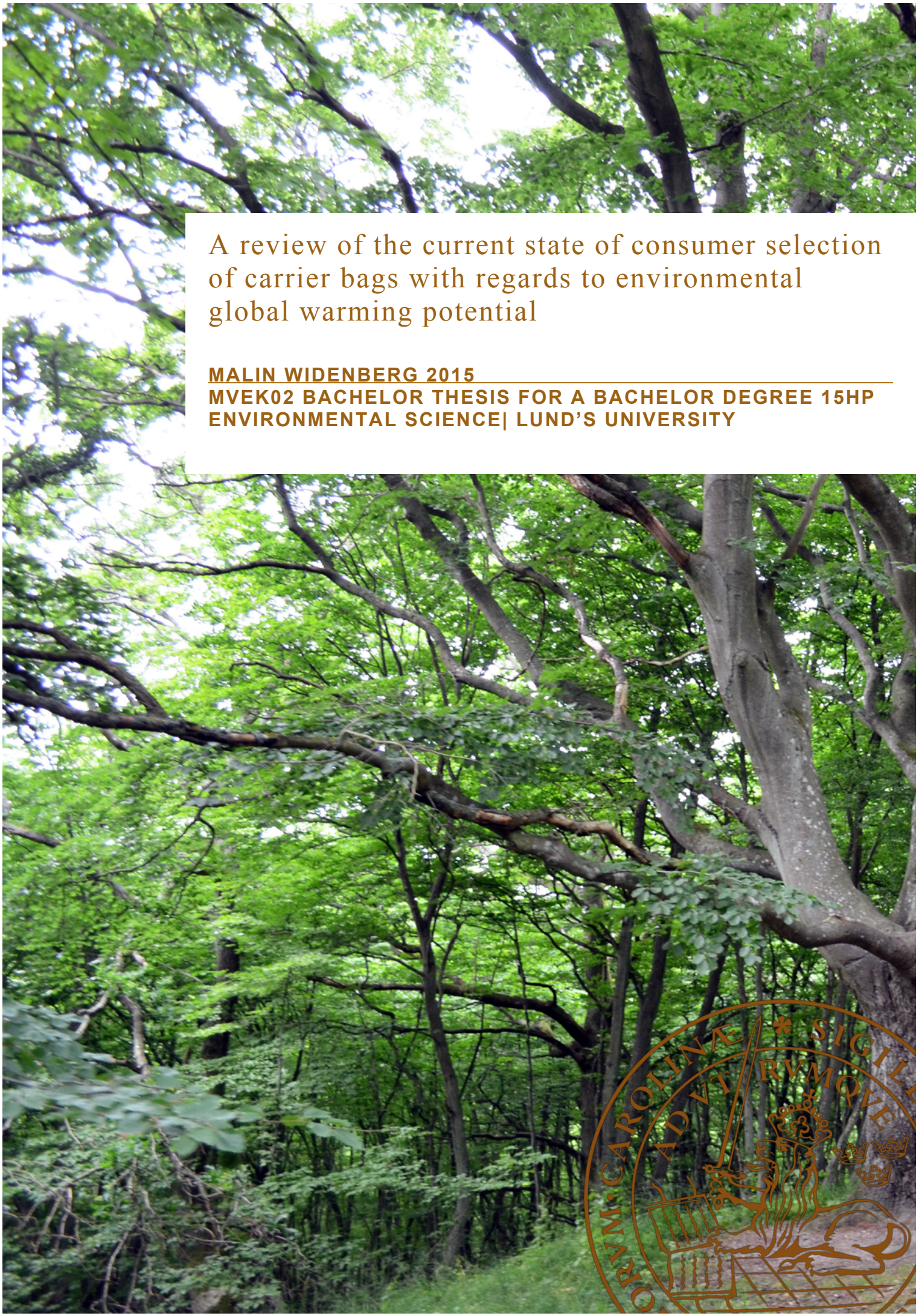

A review of the current state of consumer selection of carrier bags with regards to environmental global warming potential

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Abstract

There are several different options of carrier bags available at supermarket retailers with and estimated consumption of 98.6 billion plastic carrier bags in the EU alone. The aim of this paper is to seek insight to the environmental impacts of the different carrier bags and put this in relation to GWP values. The paper also aims to investigate the consumer selection of carrier bags in Swedish Supermarkets and their motives behind their carrier bags selection. To evaluate the environmental impacts of the carrier bags a literature review was conducted using LCA's of carrier bags and by placing these in a Swedish context. The consumption was evaluated using direct observations of customers in different Supermarkets and structured interviews were made to seek the factors behind the customer's selection. The results show that the conventional HDPE bag has the lowest GWP values for single-use and that the cotton bags have to be reused at least 173 times to achieve similar values. The observations indicated that the single-use plastic bags were the most commonly used product but that the customers preferred to use the LDPE bags as their main carrier bag. The observations also showed that the cotton bags were the most reused option and the interviews identified them as the most environmentally friendly. The interviews also identified the LDPE bags as the most transportation convenient and they were together with the single-use bags the most cost effective options. The study conclude that the most environmentally friendly option is the carrier bag that gets reused plenty of times throughout its lifespan and that the secondary value of the products may lower the GWP values together with proper disposal and end-of-life approach from the nations.

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List of abbreviations:

EU	European Union
LCA	Life Cycle Assessment
GWP	Global Warming Potential
PE	Polyethylene
HDPE	High Density Polyethylene
LDPE	Low Density Polyethylene
PP	Polypropylene
PLA	Polylactic Acid
PCB	Polychlorinated Biphenyl
ISO	International Organization for Standards

1. Introduction

Available carrier bags

Transporting groceries home from the supermarket in carrier bags is easy, convenient and inexpensive with the plastic bags having been in abundant use since their introduction to the market in the late 1970's (Mudgal, et al. 2011; Accinelli et al, 2012). In 2010 a citizen of the European Union used 198 plastic carrier bags per year, this is an equivalent of 98.6 billion carrier bags and 89% (175) of these bags were of the lightweight single-use variety (Mudgal et al. 2011). The single-use bags can be made out of High Density Polyethylene (HDPE) or Bioplastic and are consider on time use when they are thinner 49 microns (Sherrington et al. 2012).

Other carrier bag products that are available on the Swedish market include another single-use options named Bioplastic, a product that is made out of starch-polyester blends and polylactic acid (PLA) and can have biodegradable characteristics (Edward & Meyhoff Fry, 2011). The Low Density Polyethylene (LDPE) also known as "bag-for-life", paper, the Polypropylene (PP) non-woven carrier bags and textile, canvas or cotton bags are made to be reused multiple times (Edwards & Meyhoff Fry, 2011, Andersson, S., Axfood pers. com.).

Consumption of carrier bags

The Swedish consumption of plastic carrier bags was estimated at around 120 per person per year (Mudgal et al, 2011; Andersson, S., Axfood pers. com.) Further research indicating that a Swedish per capita consumption of single-use plastic bags is 100 units per person per year while the consumption in Slovakia is 466 single-use bags per person or Denmark where the number is 4 (Sherrington et al. 2012). Single-use plastic bags used by retailers in EU are mainly produced in Asia with resources extracted in the Middle East (Edwards and Meyhoff Fry, 2011). The production of PE is through distilled coal tar/peat or condensate petroleum (Rujnic-Sokele and Baric, 2014). The Life Cycle Assessment (LCA) of these products highlighted the areas of extraction, production and transportation as causing the highest environment impact (Mudgal et al.

2011). Sherrington et al. (2012) quotes that "*the rule of thumb is that it takes 2 kg of oil to produce 1 kg of plastic products*". The production of plastic around the world accounts for approximately 7-8% out of the total extraction of oil and natural gases (Mudgal et al. 2011). The EU produced around 1.12 million tonnes of plastic carrier bags in 2010 and that production account for less than 0.02 % of the world oil demand (Ibid).

The European Parliament voted on the 28th of April 2015 and ruled that the member states had to reduce their consumption of the single-use plastic bag to 40 lightweight bags per person by 2025 or that retailers would not be allowed provide single-use bags free by 2018 (European Parliament, 2015). The prohibition or levy's applied at retailers for lightweight bags has previously been implemented by other nations including China, Ireland, Australia and various American cities (Jensen & Venoka 2014). A reduction of 80% plastic bags used by the EU would lessen the impact on the environment by a 2.4 billion plastic bags littered and provide a saving of 81 Mt of CO_2 emitted to the atmosphere (Mudgal et al. 2011).

Environmental impacts

In the study by Mudgal et al. (2011) it was estimated that 4.5 billion plastic bags were discarded as litter in the EU in 2010 and of these 4 billion were of the single-use variety. Littering of plastic carrier bags has been proven to have significant environmental impacts and conventional plastic carrier bags can persist as litter in terrestrial environments for over two years, depending on compositions and environmental conditions, before they start to disintegrate (Mudgal et al., 2011). In terrestrial environments plastic not only interfere with the aesthetical values of parkland and coastal areas but due to their light weight and ballooning structure plastic bags are easily transported great distances by wind and waterways (Sherrington et al. 2012). The littered bags often become deposited in marine environment, where 80% of marine plastic litter comes from landfills and littering (Moore, J.C., 2008). Once there plastic is one of the most common persistent pollutants (Moore, J.C., 2008; Sherrington et al 2012). In marine environments the plastic carrier bags threatens its inhabitants as it can mimic food such as jelly fish and if ingested by marine mammals like seabirds, turtles, dolphins it can lead to starvation, immobility (as the animal can no longer achieve natural buoyancy) and entanglement that will ultimately cause death (Moore, J.C., 2008). Plastics have an absorbing characteristic and can absorb persistent bioaccumulating and toxic contaminants such as PCBs and DDT from the surrounding water and if the plastic becomes ingested it can biomagnify the toxins are stored in the

organism's adipose tissue (Rochman et al, 2013; Walker et al. 2012). Plastic can be transported by ocean currents into benthic environments and the plastic bags can be imbedded in the sediment and restrict gas exchange causing hypoxic or anoxic conditions that can disrupt the ecosystem (Mudgal et al, 2011). Plastic can also leach additives like phthalates and Bisphenol A that can cause endocrine disruptive effects on reproductive organs in mammals (Ivar do Sul and Costa, 2013).

Life Cycle Assessments and Global Potential Warming

To evaluate the environmental impact of a products input and output throughout its lifespan the standardized tool of ISO 14040:2006 is utilized to create a LCA that aims to promote sustainable development (Mudgal et al. 2011). The LCA determines the environmental effects from cradle to grave in five important stages including the extraction and production, the transportation, packaging, the waste management of the product and the option of recycling, reuse and a avoided production (Edwards and Meyhoff Fry, 2011). In 2011, Edwards and Meyhoff Fry published an LCA for the Environmental Agency in the UK regarding carrier bags available in Supermarkets. To determine the environmental impacts that different carrier bag exuded on their surrounding the Global Warming Potential (GWP) value in carbon dioxide equivalents were utilized (Ibid). The GWP value takes into account all the emission a product produce during its lifespan and put them into perspective of a 100 year time horizon (Ibid). A standard CO_2 molecule represents a GWP of 1 while methane (CH_4) represents a value of 21 GWP (UN, 2015).

Direction and aim of the study

The direction of this study came from the desire to investigate the consumption and environmental impacts of carrier bags. The study evolved from investigating the consumption of conventional carrier bags in Australia, where double and triple-bagging items is a common occurrence, to a comparison of the Swedish carrier bag consumption. As there was limited information of the environmental impacts of the Swedish products the study evolved to seek the environmental impact of the products available on the Swedish market without the Australian comparison.

The aim of this paper is to seek insight of the environmental impacts of carrier bags and putting this in perspective of GWP values. The paper also aims to investigate the consumer selection of carrier bags in Swedish Supermarkets and their motives behind their carrier bags selection.

Previous research (Edwards and Meyhoff Fry, 2011; Mattial et al, 2011; Sherrington et al, 2012, Mudgal et al, 2011) demonstrate environmental impact of carrier bags in other states and this paper aim to put this research into perspective of the Swedish markets conditions and consumption.

The aims of the paper will be investigated though the following questions:

- How does the different carrier bags impact the environment in relation to the GWP?
- What carrier bags do customers select at the retailers?
- What factors impact customer's selection of carrier bags?

2. Method and material

2.1 Selection of Methods

The paper has been compiled into three sections that include the most current information available on the environmental impacts on the included carrier bags. The method selected for this part of the study was a literature review. The second part was preformed as observations to investigate the public's selection of carrier bags. The third part was organized as structured interviews that sought to gain insight about the public's general knowledge and attitude regarding the different bag options. The information was compiled and presented in the results and analysed in the discussion to investigate if the public's knowledge and behaviour is reflected in the most sustainable option on the market.

2.2 Literature review

To create a broader overview of the existing options of carrier bags available to the customers in supermarkets the first search was on the homepages of the three market holding companies of the Swedish supermarket namely: ICA Sverige AB, Coop Sverige AB and Axfood AB. The ICA Sverige AB website had information about their available carrier bag options in the "Frequently asked questions" (Vanliga Frågor) section under the tab "Climate – Environment – Social responsibility. No information was available on Axfood ABs webpage but information was given upon request through email. Information regarding Coops options were available though a press release from the 4:th of July 2014 available on their website.

The scientific materials for the literature review were obtained by using the search engine LUBsearch, the search word used was "Plastic bags" and revealed an article by Rujnic-Sokele and Baric (2014). In reviewing the references of this article to gain further information on different LCA's bags I came across a reference from the Environmental

Agency in the UK, but were unable to find the specific publication referred to. To find the desired publication the Google search engine was used with the search words “LCA Environmental Agency”. The publication by Edwards and Meyhoff Fry (2011) contained information on a UK level and further information Swedish level was investigated by using the Google search engine, but no information was found using the search words “Sweden” “LCA” “Plastic” “Carrier bags”. To see if there was additional LCA available on a EU level the following search words were used on the website Europe.eu: “LCA” “Carrier bags”. The search revealed a proposal to the European Commission to reduce the use of single-use plastic bags and contained the studies by Sherrington et al. (2012) and Mudgal et al. (2012).

In the study by Sherrington et al. (2012) information regarding Swedish conditions was available and used to relate the UK LCA to the Swedish condition that might vary the impact the environmental impacts of the different carrier bag options. The Swedish conditions were further enhanced with information from the different supermarkets webpages.

2.3 Observations

To be able to get an understanding about the current consumption of carrier bags, direct observations (Esaiasson et. al. 2009) were conducted on Saturday the 18th of April 2015. As with the interviews the aim was to collect a wide variety of data so no one category of shoppers was present. The observations were conducted at three different stores. The first observation was conducted at 11am at Coop Nova, which were the largest of the three supermarkets. The second observation was conducted at ICA Mobila Lund at 1pm and the third at ICA Malmborg Lund at 3pm that were the busiest of the three as it was next to the train station. To obtain a randomized selection of consumers a die was tossed to determine the selected register. The die was also used to select which side of the conveyor belt was observed and the conveyor belt at each location was observed for 20 minutes from a position that had clear view over all the items that travelled down the conveyor belt. The following observations were made:

- The Sex of the shopper
- How many plastic bags the person used.

- If the person had brought (reused) their own bag(s) to use only and what kind i.e. Cotton, LDPE (plastic), single-use bags, paper, non-woven PP or other.
- If the person has brought some of their own bags but still collect single-use plastic bags.
- If the person only used single-use plastic bags supplied to them from the supermarket.

The results from the observations were compiled in Figure 1-5 in the result section.

2.4 Interviews

To gain information regarding the public's general knowledge concerning their carrier bag selection a structured interview (Esaiasson et. al. 2009) was conducted outside a Swedish supermarket. The interviews were conducted on Sunday 19th of April 2015 and the date was selected so that there was a wide variety of shoppers visiting the supermarkets representing a wide selection of opinions. To make certain that not only one category (i.e. seniors, students, family's) of shoppers were selected the interviews were conducted in 20-minute intervals at 11 am, 1 pm and 3 pm. The people selected for the interview were determined at random by utilizing a die. After each conducted interview the die was tossed and as the customers exited the store the number on the die represented the person approached and the customers were asked the following questions:

- What is their age?
- What is their gender?
- What kind of bag have you used today?
- Why did you decide on this carrier bag?
- Is this your usual selection of bag used?
- Do you utilize the bag for other aspects?

The questions were designed to investigate the general opinions of the costumers and to collect the knowledge they used to base their decision on. The interviews were then compiled in a Table 3 and presented in the results.

2.5 Limitations

In collecting information for the environmental impact of the different carrier bags available in Swedish supermarkets it became clear that there was limited information on the full LCA for the products. The information obtained from EU LCA does not take into account specific Swedish practices, which could possibly result in a more appropriate GWP. This includes incineration of waste material for heat recovery programs.

In approaching the randomly determined people for the interview it was sometimes hard to engage in the interviews as there were many people trying to gain the shoppers attention to promote products or to ask for donations, thus the amount of interview conducted were limited.

In the observations it was hard to determine if the single-use plastic bags were made out of Bioplastic of HDPE material and there were no definite answer regarding the three stores product. This was due to that it was hard to gain permission from the supermarkets to conduct the observations on a weekend thus making it hard to approach the supermarket in gaining information regarding their carrier bag options. Further information was requested thought email but no information has been received.

For the observation costumers using the self-scanning option were excluded, as observations about their HDPE bag consumption were impossible as there were no need for them to have their items on a conveyor belt.

3. Results

3.1 Literature Review – GWP of carrier bags

The text that follows explains the environmental impacts that the different carrier bags exude on the surrounding environment. The GWP values will be presented in Table 1 and discussed for the different bags under their individual heading. The results will further present the different environmental impact areas of the bags followed by how the different Swedish market conditions. The general diffrences will be presented at the end of the literature review while the indivudual changes for the bags is presented under each heading.

There are some differences between the HD and the LD polyethylene products. The LDPE was the first product developed and has a low water absorbing quality and the material is also chemical resistant, though and flexible (Rujnic-Sokele and Baric, 2014). The HDPE products have low cost and share similar characteristics with LDPE but has a 4 times higher tensile strength, but even thou the HDPE products are stronger they are more prone to warping and shrinkage (Ibid).

The different carrier bags GWP is summarized in Table 1 below and their required number of reuse needed to share similar GWP.

Table 1: Summary of the different carrier bags options available to the Swedish market and their environmental impact described in GWP (Kg CO_2 equivalent) and their required number of reuse for them to achieve similar GWP value (Values compiled from Edwards and Meyhoff Fry, 2011)

Type of Carrier bag	GWP single use	No. Of reuse	GWP with reuse
HDPE	2.082	1	1.578
Starch-polyester	4.691	1	4.184
Paper	5.523	4	1.381
LDPE	6.204	5	1.385
Non-woven PP	21.51	14	1.536
Cotton	271.533	173	1.579

3.1.1 HDPE – High Density Polyethylene

The conventional single-use plastic carrier bag is made out of HDPE and weighs 7.5-12.6 grams with a volume of 17,9-21.8 litres leaving it with a carrying capacity[1] of 5.88 items (Edwards and Meyhoff Fry, 2011). Using the carrying capacity and the functional unit of 483 items it would take at least 82 HDPE bags for the customers to transport the items from the supermarket (Ibid).

The GWP value for a HDPE single-use bag is 2.098 kg Co_2 equivalent where the greatest environmental impact comes from the extraction and manufacturing of the product in the China (Ibid). This process account for around 58% of the GWP as 78% of the Chinese grid energy derives from coal (Ibid). The HDPE bag made from regular PE is made from crude cracked oil turned into gasoline or from natural gas mix of methane, ethane and propane (Rujnic-Sokele and Baric, 2014). In 2006 the EU imported around 98% of HDPE bags from China, Indonesia or Malaysia (Sherrington et al. 2012). The total transportation of the product account for 21% of the GWP as the raw material (crude oil and natural gas from the Middle East) is transported to manufactures and then onwards to the retailers (Edwards and Meyhoff Fry, 2011). Recycling programs of HDPE bags carry additional environmental impacts in additional transportations emissions of the recycled material to China (Mudgal et al. 2011)

When 40.28% of HDPE bags are reused the GWP value decrease to 1.578 kg Co_2 equivalent (Edwards and Meyhoff Fry, 2011). This is due to the avoided need of production of bin liners and the costly extraction of virgin resources becomes replaced (Ibid).

The Swedish market also use of single-use HDPE bags that contain green Polyethylene, a product called "I'm Green™" that was developed by Braskem in 2010 (Andersson, S., Axfood AB, pers. com.; Braskem, 2015). The I'm Green™ product is produced by 100 % renewable resources by creating ethanol out of sugarcane (Braskem, 2015). Ethanol can produce green PE bags with the same carrying capacity as regular HDPE, while utilizing the same equipment as regular PE production (Ibid). The product is also available in Coop supermarkets

[1] The Carrying capacity was based on the functional unit of customers 4 week shopping in the UK during the data collection in 2006/07 and accounted for 483 items using the mean weight and volume of the different bags (Edwards and Meyhoff Fry, 2011)

while ICA AB had a starch-based bioplastic bag with 30-40% corn-starch (ICA Sverige AB, Coop Sverige AB, 2014).

3.1.2 Bioplastic (Starch-polyester blend bag)

There are several different compounds that can make up the Bioplastic bag. In the study conducted by Edwards and Meyhoff Fry in 2011, the bioplastic bags were made out of PLA with either a plant-base starch or a blend of polyester derived from hydrocarbons together with starch from corn, potato, tapioca or wheat (Ibid). The bag has a weight of 15.8 grams and has a volume of 18.3 litres with a carrying capacity of 5.88 items (Ibid).

The GWP estimated in the study by Edwards and Meyhoff Fry (2011) the starch-polyester blend bags has a GWP of 4.184 Kg Co_2 equivalent when 40.28% of the bags are reused. The extraction and production process account for around 56% of the total GWP and the waste process account for around 30% (Ibid). The bags that have biodegradable characteristics decompose into CO_2, CH_3, H_2O, biomass and inorganic compounds (Mudgal et al, 2011).

During production of Bioplastic bags in the USA it has been shown that the bioplastic option is 80 % more environmentally friendly than regular plastic bags when the energy used to produce the Bioplastic bags is made out of clean and renewable geothermal energy (Khoo, et al., 2010). The energy used to produce the starch bags in Norway is 99.1% hydropower but the transportation of the produce from Italy to Norway by Lorry account for 21% of the total GWP (Edwards and Meyhoff Fry, 2011).

3.1.3 Paper

The paper bags evaluated in the LCA for the Environmental Agency in the UK weighed 55.2 grams with a volume of 20.1 litres and has a carrying capacity of 7.43 items (Edwards and Meyhoff Fry, 2011).

The paper bag has a GWP of 5.523 for single-use that is due to the high production cost on the environment for the extraction and production of the raw material that account for over 70 % of the GWP (Ibid). The GWP of the bags is reduced to 1.381 Kg Co_2 equivalent when reused 4 times (Ibid). If the paper bags were to be recycled at the end-of-life their GWP value would decrease to 1.090 Kg Co_2 equivalent (Ibid).

Scandinavia has lots of trees and a local production of paper bags that reduce the amount of transportation required (Mattila et al. 2014) The paper bags sold in Swedish retailers are marked as FSC (Forest Stewardship Council) grade paper and maintain responsible forest management (FSC, 2015). For each paper and plastic bag sold by Coop AB they donate 0.03 SEK to Vi-Skogen that work towards increasing living standards for people living in poverty by planting trees and to create a sustainable environment (Coop Sverige AB, 2014; Vi-Skogen, 2015).

3.1.4 LDPE – Low Density Polyethylene

The LDPE bag is the traditional carrier bag used in Swedish supermarkets, but the LDPE option used in the study by Edwards and Meyhoff Fry in 2011, the "bag-for-life" are not a bag that more commonly used in clothing stores in Sweden. In relevance of this paper their research will be used with additional information on the different Swedish options.

The heavy duty LDPE bags weighs of 27.5-42.5 grams with a volume of 19.1-23.9 litres and has a carrying capacity of 7.96 items (Edwards and Meyhoff Fry, 2011). The traditional Swedish bags are 35-38 microns thick (Forne, 2014)

The environmental impact is highly reflected in the raw material production for the LDPE and account for 65% of the GWP. When there is no reuse applicable the GWP has a value of 6.924 Kg CO_2 equivalent (Edwards and Meyhoff Fry, 2011). To obtain a similar value to the reused HDPE bag the LDPE need to be reused 5 times to achieve a similar GWP value of 1.385 Kg Co_2 equivalent (Ibid).

It needs to be noted that there are several new options of LDPE bags available on the market that will have impact on the GWP values stated above. As of 2014 the I'm Green™ product is now available in LDPE (Braskem, 2015). Axfood AB is now utilizing this greener option and state that their products have a reduced CO_2 emission by 70-75% compared to regular PE products (Andersson, S., Axfood pers. com.). Coop AB have also invested in RPET (Recycled PET bottles) LDPE bags and ICA AB stated that their "Miljökasse" contain 60-90% recycled material (Coop Sverige AB, 2014; ICA Sverige AB).

3.1.5 Non-woven PP (Polypropylene)

The non-woven PP bags are designed to be reused multiple times and have a more structured design and a semi rigid bottom inlay to improve its stability and this its carrying capacity (Edwards and Meyhoff Fry, 2011). The bags have a weight of 107.6-124.1 grams with a volume of 17.7-21.8 litres and a carrying capacity of 7.3 items (Ibid).

The non-woven PP bags are mainly produced in East Asia and environmental impact values are reflected in the extraction and production processes that share a similar process as that of HDPE and LDPE and account for over 75% of GWP values (Ibid). To produce 1 kg of PP monomers it requires 1.22 kg of crude oil and 0.4 kg of natural gas catalyst with using magnesium chloride and titanium chloride (Khoo et al. 2010). The non-woven PP bags have a single-use GWP value of 21.510 Kg CO_2 equivalent and need to obtain a reuse value of 14 times to achieve a GWP value of 1.536 Kg CO_2 equivalent (Edwards and Meyhoff Fry, 2011).

The non-woven PP bags share the characteristic of the plastic bags that they are water and dirt resistant but are more durable (Mudgal et al. 2011). Self-scanning customers commonly use the PP bags as the stable design improves the packing of the products (Andersson, S., Axfood, pers. com.).

3.1.6 Cotton bags

Designed to be reused multiple times the cotton bags vary in size depending on its origin and has the greatest carrying capacity of the evaluated products with up to 10.98 items per bags with its volume of 17-33.4 litres and a weight of 78.7-229.1 grams (Edwards and Meyhoff Fry, 2011).

The extraction and production process account for more 98% of the GWP values and the single-use GWP value is 271.533 Kg Co_2 equivalent (Ibid). For a cotton bag to obtain a similar value of the reused HDPE bag it needs to be reused a total of 173 times thus obtain a value of 1.570 Kg Co_2 equivalent (Ibid).

In the study by Edwards and Meyhoff Fry (2011) the cotton textile referred to in the text were not organic thus it has a 46% higher GWP than organic cotton (Textile Exchange, 2014) used by both Coop and

ICA stores (Coop Sverige AB, 2014; ICA Sverige AB). The GWP for conventional cotton fibres were 1,808 Kg CO_2 equivalent compared to the organic cotton fibres that had a GWP of 978 Kg CO_2 equivalent (Textile Exchange, 2014).

3.1.7 Swedish conditions

The UK end-of-life recycling and waste programmes have some major difference compared to the Swedish waste system. In the study by Edwards and Meyhoff Fry (2011) the data was analysed using the end-of-life approach where 14% were incinerated and 86% of waste were deposited in landfills, using data from 2008/07. Compared to this the Swedish waste program in 2010 sent 1.7% to landfill while 97.2% was sent to incineration plants that utilize heat recovery programmes (Sherrington et al. 2012). In comparison the UK sent 80.5% of waste to landfill and 19% to incineration plant in 2010 (Ibid).

The secondary use of LDPE bags as in liners and that several municipalities are working together with the supermarkets in using a colour coded system for recycling and waste programs (Forne, D., 2014). Incineration can recover around 80% of the calorific value of the plastic but does not replace the avoided production of new virgin material (Mudgal et al. 2011). The calorific value is calculated using virgin fossil based resources (Ibid). To purchase bin liners is supermarkets average cost of €79.26 (Mudgal et al. 2011) and are available in HDPE, LDPE and recycled LDPE (Personal observation in different supermarkets).

Only the HDPE bags and the Bioplastic bags are available free of charge in Sweden. The other bags are available for purchase either in the start of the store for self-scanning purposes or by the charier registers. The prices range from 1.5 SEK for an LDPE bag and a cotton bags cost from 39 SEK for an organic cotton bag (ICA Sverige AB; Coop Sverige AB, 2014). The costs are according to Andersson, S. (Axfood) pers. com., an incentive by the company to reduce customer's consumption of plastic bags.

3.2 Observation

For the observation a total of 85 customers selections of carrier bags were observed with a total number of 201. The total amount of bags used can be viewed in Figure 2 and described in %. The figure show that over 50 % of the bags were of the single-use option and that the second most common bag used were the plastic (LDPE) bags. The other value stands for people who transported their goods using a carrier function that has not been discussed in this paper.

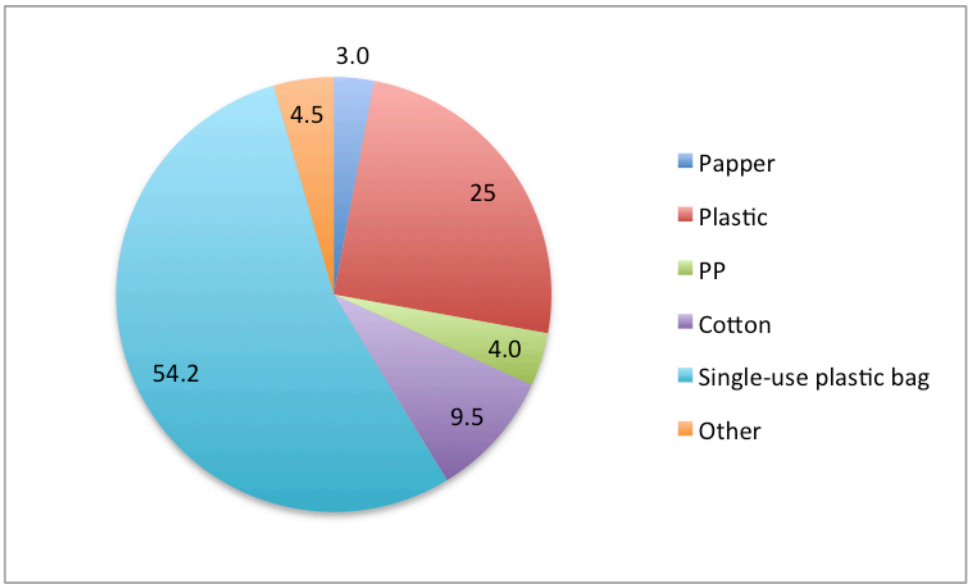

Figure 1: Diagram of total amount of bags used (201) showed in % with values of the different bags used indicated next to the bags designated colour.

Out of the total 201 carrier bags used of these 109 were single-use and out of the 85 individuals observed, 28 individuals used multiple bags while 26 used one single-use bag. This is illustrated in Table 2.

Table 2: the following table describe the single-use plastic bags distribution among the observed costumers ranging form not applicable to multiple uses.

Single-use plastic bags used	
Total observations	85
Not used	31
One bag used	26
More than one used	28

The main carrier bag selection is shown in Figure 2 and show that the LDPE bag were the most commonly used bag with 50 bags used out of the 108 observed. The second most common bags used were the cotton option followed by the single-use bags. The numbers in the pie chart indicate the number of bags that were observed.

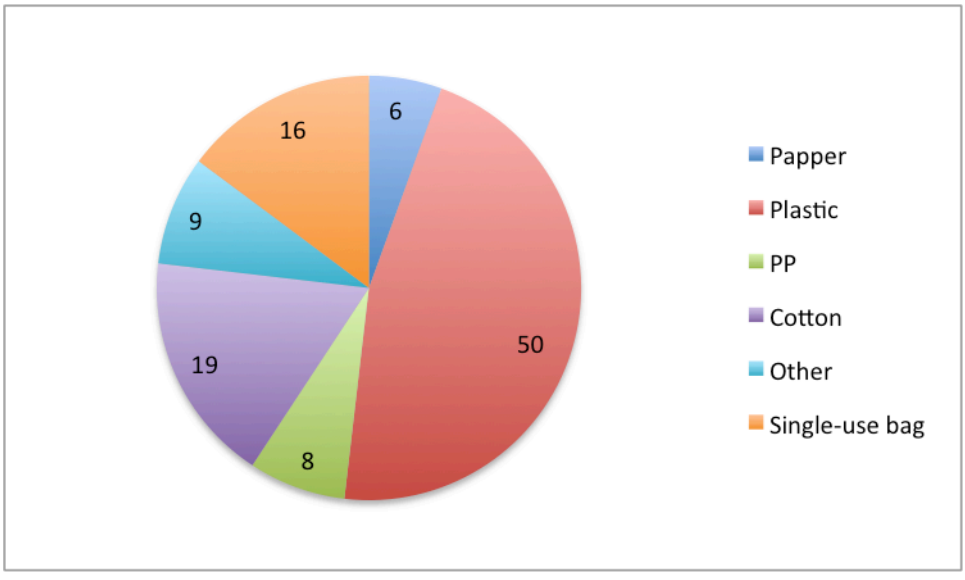

Figure 2: Amount of bags used as main carrier bag. Number indicate amount of bags observed

Figure 3 and 4 show how many of the different bags were reused by the two sexes. Figure 3 show that men mainly reused plastic (LDPE) bags followed by cotton bags and there were no observations made of reused paper bags. For the women the main bag reused were the cotton bags followed by the plastic (LDPE) bags. The total amount of reused bags by both sexes is visualized in Figure 5.

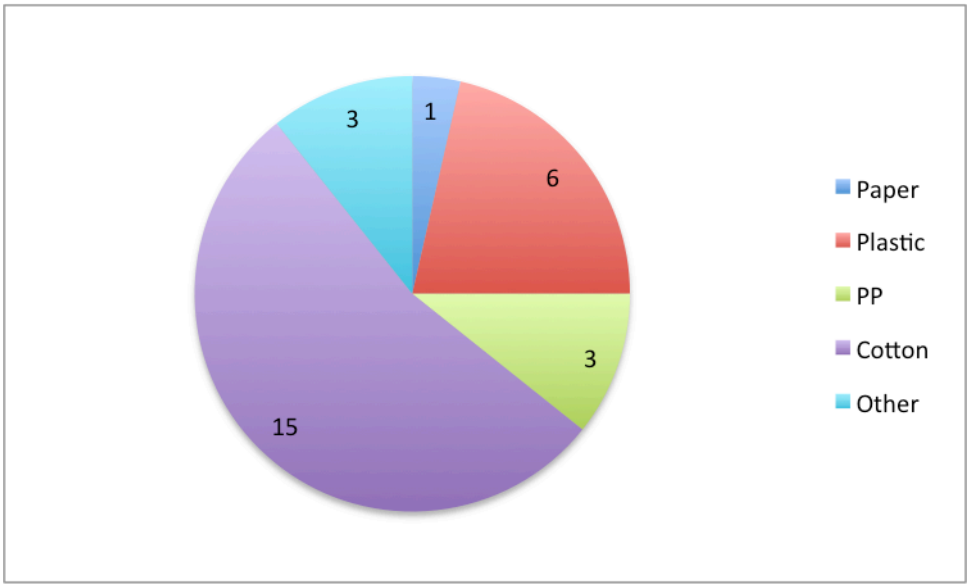

Figure 3: Amount of carrier reused by females. Number indicate amount of bags observed

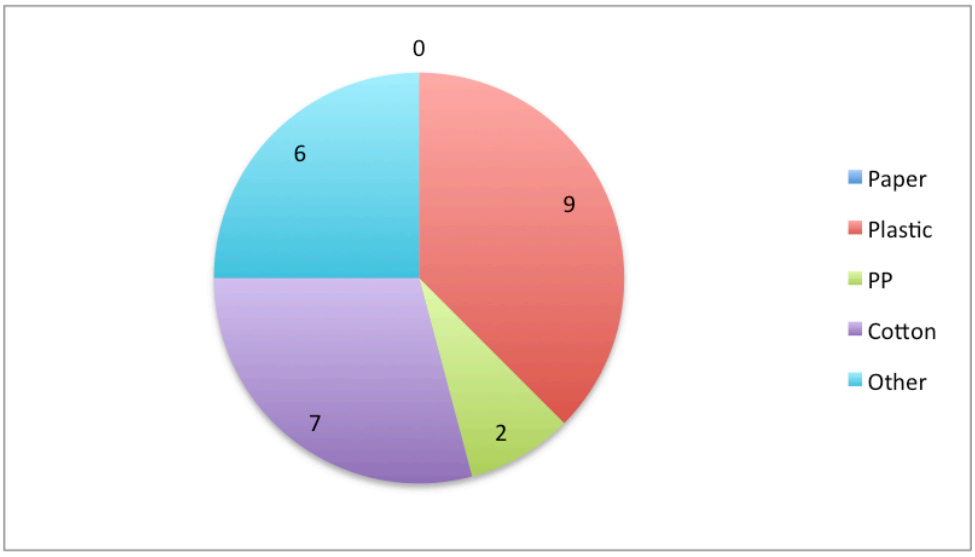

Figure 4: Amount of carrier bags reused by males. Number indicate amount of bags observed

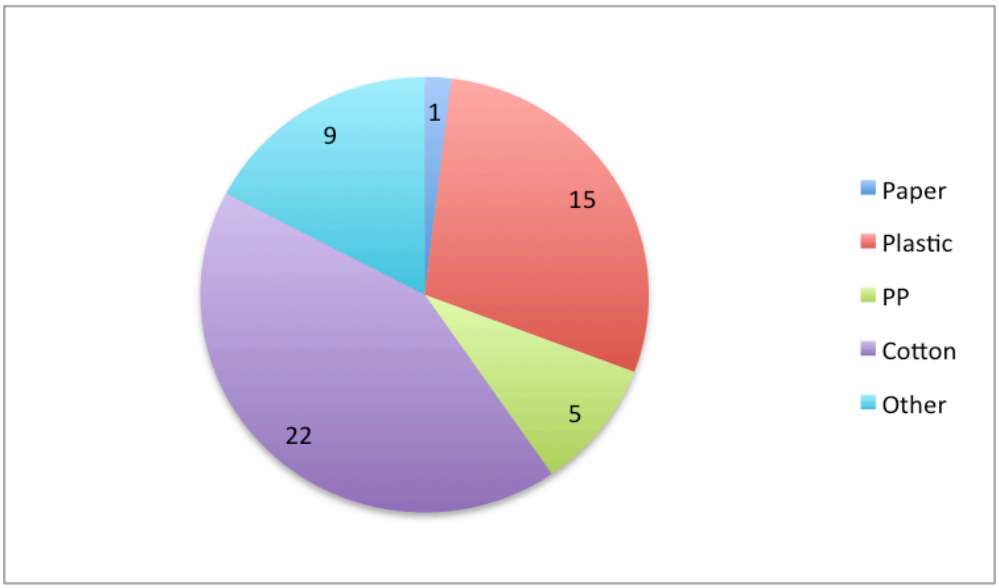

Figure 4: Total amount of carrier bags reused. Number indicate amount of bags observed

3.3 Interviews

A summarized version of the conducted interviews can be found in Table 2 below. The main type of carrier bag used was the cotton bag as the customers felt like this option were the most environmentally friendly option and the most cost effective. The LDPE bags were mainly utilized for their convenience in transporting the items home and that they are the most cost affective option compared to the other multiple use options. The HDPE option were mainly used for consumers with few items, as it was a free option that made it able to transport home the goods at no cost. The table don't take into account if the costumer reused any of the products.

When asked if the customers reused their carrier bags only one person answered no. For the LDPE bag 100% of the people said that they used is as bin liners. For the cotton bag 4 people stated that they only used the bags for shopping while the remaining 2 people said that they used it in everyday use, either as hand, gym or schoolbags. For the single-use bag there were two participants and for reuse one female stated that she always utilized the HDPE bags for pack lunches while the second female stated that she mainly used them for their cost and convenience and that she did not reuse the bag.

Table 3: summarized table of the interviews

Age	Sex	Type of carrier bag	Why?	Usual selection?	Do you reuse the bags?
55	F	Single-use	Cost	No, mainly use paper	Yes, I use the HDPE bags for lunches and the paper bags to the recycling.
40	F	Cotton	Cost	Yes	Yes, but I mainly reuse them for the shopping.
23	M	LDPE	Transportation	Yes	Yes, I reuse the bags as rubbish or as a to cover my bike seat when its raining or to.
24	F	Cotton	Cost/Environment	Yes	Yes, I also use them as handbags and pretty much for everything, everyday.
22	F	Cotton	Environment	Yes	Yes, but I mainly reuse them for the shopping
61	M	Cotton	Cost	Yes	Yes, but only for shopping
56	F	Cotton	Transport/cost	Yes	Yes, but only for shopping
46	M	PP	Environment/Cost	Yes	Yes, The plastic we reuse as bin liners at home and the girls use the cotton bags as their gym bags. The PP bags are only really for the weekly shopping
29	M	LDPE	Transportation	Yes	Yes either as garbage bags, but the new bag with RPET can't hold the same weight as the old bags did and they tend to break on your way home from the shop
32	F	LDPE	Transportation	Depends on the circumstances	Yes, as bin liners
15	F	Single use	Cost	Sometimes	No
26	F	LDPE	Transportation/cost	Half of the time	Yes, as a garbage bag
32	M	Cotton	Environment	Yes	Yes, but only for shopping

4. Discussion

This study demonstrates that the most environmentally friendly option are the carrier bags that are reused several times within its lifespan. The observations show that consumers frequently use the single-use option but prefer to use the LDPE bags as the main carrier bag and that the preferred reused bags were the cotton bags. The interviews found that the consumers identify the cotton bag as the most environmentally friendly option but also that the LDPE bag has a high secondary value as bin liners.

The available carrier bag options in supermarkets all have their own advantages and disadvantages as reflected in their cost, transportation efficiency or environmental impact. For a carrier bag to be cost effective with good carrying capacity the product often have a more severe environmental impact due its increased resource demand for production that leads to higher extraction and production emissions. In the study by Edwards and Meyhoff Fry (2011) the product with the least GWP per single-use was the conventional HDPE bag while the cotton bag had a GWP value that was over 130 times larger then the HDPE bag. The HDPE bags are considered to be single-use but have a large secondary value, as bin liners and in some extent decrease the need for additional production of specific bin liners thus decreasing avoided emission though this production (Sherrington et al. 2012; Mudgal et al. 2011; Edwards and Meyhoff Fry, 2011; Mattila et al. 2011). With increased use the GWP values will decrease as it will decrease the demand on production thus lowering the need for increased material production and extraction. The recycling value of the HDPE bag are low and increase environmental impact with additional transportation emissions but heat recovery though incineration can retain up to around 80% of the calorific value (Mudgal et al, 2011). The more resource intensive products were designed to be reused multiple times as reflected in Table 1, both in their GWP values and their amount of reuse required. For a cotton bag to be share the same environmental impact as a reused HDPE bag it need to be reused at least 173 times, but is this a valid number and do customers reuse their bag in such a large scale?

The customer's consumption was observed and is presented in the results. Figure 1 displays the total distribution and consumption of

the different carrier bags while the amount of reused plastic bags were presented in Figure 3 and 4 depending on the sex of the customer. These results indicate that over 54 % of the bags consumed were of the single-use variety and these were never reused by any of the sex's. The single-use bags were used as the main carrier bag in 15 % of the cases, but was also used to contain items that weren't commercially packed/wrapped and were used by 64 % of the customers where 33 % used more than one. Out of total of 201 bags observed, 25.9% were reused and females reused 54%. Amongst male and female shopper there was a difference in which bags were reused. The female shopper reused the cotton bag option while the men selected to reuse the plastic bags with only one occurrence where the paper bag was reused accounting for 2% of the reused bags total. So what does the customers action say about their selection? Why are people motives when the select the amongst the available bag options?

During the interview three main categories of selection were identified: cost efficiency, transportation convenience and environmental consciousness. The LDPE bags were identified as the most convenient bag for transportation and also a cheaper more cost effective option. All the interviewed people stated that they used the LDPE bags as bin liners. One person stated that the new bag material did not have the same carrying capacity as the old product and that the product often broke during transport. The cotton bags and the PP bags were here identified as the most environmentally conscious choice amongst the consumers and also a cost effective option as most costumer stated that they all reused the bags for shopping and some for everyday activities. The single-use bag was available free of charge for the customers and were mainly chosen for this purpose.

On the 28th of April 2015 a press release from the European Parliament it was stated that the European Commission planned to reduce the member states lightweight plastic bag consumption by 80% to 2025 (European Parliament, 2015). The estimated number of littered single-use plastic bags in 2010 in EU was 3.9 billion and with the reduction target of 80% by 2025 (Mudgal et al. 2011) this would in mean a possible reduction of littered bags by 3.12 billion. In Sweden, the plastic bags are 35-38 microns thick and retailers believe that the ban of this product will cause further environmental impacts as the resource demand will increase to make the products compatible with the EU standards (Forne, 2014). So even though there will be a reduction of littered bags there are possibilities that there will be increased emissions due to increased material production. The worst end-of-life approach was to deposit the waste in landfills, as possible leached methane has a 21 times higher GWP than carbon dioxide (Edwards and Meyhoff Fry, 2011). A heat recovery program can retrieve

up to 80% of the calorific values of plastic thus decreasing the demand on heating by fossil based sources (Mudgal et al, 2011). But for the LDPE bags to retain their secondary use as the bin liner the bag need to retain their carrying capacity to reduce tearing or costumers need to purchase more bags that will further encourage continuing high productions.

The most environmentally friendly bag is in relation to the GWP values in study by Edwards and Meyhoff Fry (2011) the conventional HDPE bag, especially when they that are reused as bin liners or with other secondary uses. On the Swedish market the conventional HDPE bags are more commonly used for fruits and freezer bags while the LDPE bags are used as bin liners (Forne, 2014). According to Table 1 the LDPE bags has to be reused at least 5 times to obtain the same value as the HDPE bag but there are differences that might change be GWP value and thus the number of times the bags need to be reused. The LDPE bags with green PE have a much lower emission rate than that of regular LDPE and the end-of-life approach with heat recovery (97.2%) instead of being deposited in landfills (80.2%) (Sherrington et al. 2012) will further improve the GWP value. This system need to be further investigated to evaluate if this is the more environmentally sustainable option. The observations shows that LDPE bags are the mot commonly used main carrier bag

The interviews showed that people believed that the cotton bag were the most environmentally friendly option and as it contained more sustainable materials like organic cotton and were strong to enough to sustain frequent reuse. The research showed that organic cotton has a 46% reduced emission (Textile Exchange, 2014) compared to regular cotton thus the extraction and production costs that make out 98% GWP in the study by Edwards and Meyhoff Fry has values has to be re-evaluated. With the revaluated value of the GWP the amount of times the cotton bags had to be reused would also change. To reuse a cotton bag at least 173 times can questioned as practical but it does make one put into perspective the amount of times one reuse the product.

The location of shop for the observations played a large role in the customer's consumption. The largest of the three stores still had a wide variety of shoppers from the different age group and categories but these customers also purchased more items that required more carrier bags and costumers that choose the self-scanning service thus excluding them from the study. The third store was located by the train station and even thou there were a wide variety of customers most would purchase small amount of items and choosing convenient and cost effective options instead. For improved results these observations and interviews should have been

conducted over several days to include more data to evaluate if there were statistical relationships among the different categories of consumers and carrier bags.

5. Conclusion

"The analysis showed that the environmental impact of each type are significantly affected by the number of times a carrier bag is used" Edwards and Meyhoff Fry, 2011

The GWP values reflected in Table 1 indicate to some extent the environmental impact the different carrier bags have on their surrounding but the changing conditions stated in the results may alter these values and thus their environmental impact. The option with the lowest GWP value were the HDPE bag but with its large consumption and production, large littering risk and an estimated secondary use of 40.28% it still pose a threat to the environment. The LDPE bags needed to be reused 4 times to lower its GWP to share similar values, but through consumer demand retailers are now choosing more environmentally friendly material such as Green PE that has reduced mission of 80% (Andersson. S., Axfood pers. com.; Braskem, 2015). This environmentally friendly product combined with heat recovery programs will further decrease the environmental impacts that the LDPE bags have on their surroundings. The plastic LDPE bags were a popular choice by consumers investigated in the observation and were identified as the most common bag used as a main carrier bag. The interview identified them as both convenient and cost effective, they were a cost efficient option inside the supermarket and served a secondary function as a bin liner, accordingly the costumer avoided the added cost of purchasing additional bin liners. The cotton bag were the most reused carrier bag in the observation and were identified by customers as the most environmentally friendly option and with improved material production may decrease their GWP.

As the products and recycling processes are evolving, a new LCA of current products and systems needs to be conducted on a EU level and on a national one for comparison. This study does not include expected lifespan of the products or the estimated amount of reuse the product are expected to sustain, this would be a valuable resource and a recommendation for future research.

This paper is an important tool as it bring up relevant knowledge of environmental impacts of the available carrier bags and bring these into relevance of customers consumption and the required reuse of the product for them to reduce their own environmental impact.

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