Comparative Study on Environmental Impacts of Grocery Bags through LCA

by

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the

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Approved by,

(Azman Bin Zainuddin)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

December 2010

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

MOHD BURHANUDDIN BIN RUSLAN

ABSTRACT

This project was conducted to compare the environmental impacts of two types of grocery bags which are High Density Polyethylene (HDPE) plastic and paper by subjecting them to Life Cycle Assessment (LCA). Around 95% of plastic bag used nowadays end up as wastes causing many concerns including solid waste pollution caused which might not be biodegradable. Other problems highlighted are environmental impacts from the production process, and also possible impacts from use and disposal of bags. This project focuses on the environmental impacts of every stages involved in a life cycle of grocery bag. This comprises the raw material acquisition process, manufacturing process, use, recycle, and waste management. The first stage in the project is the goal definition and scope. This stage involves planning and setting the parameters for LCA. The second stage is the inventory which includes database on the theoretical calculation, interview, measurements, and literature search of the study. The third stage is the interpretation of data which obtained through inventory stage. This stage involves the classification of the inventory table into impact categories and evaluation of environmental impacts. The final stage in the project the improvement assessment or the decision making stage. Based on analysis, HDPE bags contributes more to global warming due to the greenhouse gases (GHG) emission from production process while paper bag uses more energy in paper processing. Paper bag has bigger impact on landfill and also paper bag uses less non-renewable resources compared to plastic bag. The result however is not decisive because the environmental impacts analyzed may be viewed differently.

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CHAPTER 1

INTRODUCTION

1.1 Project background

Plastic bag is the most common type of grocery bag used in many countries for decades. Most of the plastic bags are provided at supermarket, restaurant, convenience stores, and other shops. Plastic bags are commonly given to customers for carrying goods without any charge. Most of the used bags are then disposed and some of them are recycled. The plastic bags are designed to be used once and then disposed.

Plastic bags are made from the derivation of natural gas. The material used is polyethylene which is a thermoplastic polymer but the derivation varies according to the application of the design. There are several types of polyethylene such as High Density Polyethylene (HDPE), Cross-linked Polyethylene (PEX), Medium Density Polyethylene (MDPE), and other types. The classification of polyethylene is categorized based on the density and also the mechanical properties. The material used for plastic bags is High Density Polyethylene (HDPE).

The increasing number of disposed plastic bags has been an issue that concerns people all over the world. The property of non-biodegradable of the plastic bags creates the landfill problem and also can be hazardous to animal life. Littering is often the biggest problem faced by many countries and environmental development agencies because only a few percent out of billions of plastics bags used are recycled and reuse. Malaysia also affected by the landfill problem, according to Malaysian Plastic Manufacturers Association chairman, Lim Kok Boon the plastics constitute 24% of landfill volume, the second largest after food waste.

Nowadays many countries endeavor to solve this particular environmental problem caused by the plastic bags. In Malaysia, the latest effort done by the government is the Subang Jaya Municipal Council's plastic-free campaign which is launched in August 2009 with a declared aim of turning the Selangor municipality into the first place in the country to eliminate the use of plastic bags by 2010. The public also encouraged to move to other alternatives such as paper bags, biodegradable carriers or their own shopping bags by reusing used bags. The government also urges people to practice the recycle and reuse culture.

In recent years, many alternatives products have been introduced to replace plastic bags. The most common alternatives are the paper bags and woven bags. Although the material used for these alternatives are biodegradable which is an important aspect in grocery bags but this fact is not enough to support that the alternative are better that the former design, High Density Polyethylene (HDPE) bags. Some of the factors that need to be considered are the consumption of resource, water and material.

A comparative study on the environmental effects of different types of grocery bags through Life Cycle Assessment (LCA) is conducted to help determine the best environmentally type of grocery bag. LCA comprises the life chain or life cycle of product and its impacts to the environment. This assessment will provide the information for retailer and consumer on the environmental impacts of plastic bag, paper bag, and degradable bag. In addition, this study also help decides the most environmentally preferred type of grocery bag.

1.2 Problem Statement

Plastic grocery bags as litter caused many impacts to the environment such as creating visual pollution, having harmful effects on animal, landfill problem, and others. In the recent years, many alternatives have been introduced by manufacturer of grocery bags to reduce the consumption of plastic bags but the number of alternative, material, and features raises confusion to the consumer and retailer. Which types of grocery bag is the most environmentally preferred?

The problems which will be the subject of discussion are: the energy usage, the emission to environment, the waste produced, and resource used.

1.3Objective

The aim of this project is to conduct LCA on the environmental impacts of two types of grocery bag which are plastic (HDPE) and paper through LCA. On the other hand it will provide guidance to the retailer and consumer on environmental impacts of each type of grocery bag. The main outcome of this research will determine the most environmentally preferred grocery bag.

1.4 Scope Of Study

This project focuses on the environmental impacts of plastic (HDPE) bag and paper bag. It comprises the impacts from all the life cycle stages of grocery bags starting from raw material acquisition, manufacturing processes involved, use, reuse, and recycle or waste management. The output of this project will be in the form of comparative data on impacts to the environment using parameter.

1.5 Significance Of Study

This project provides analysis on the environmental impacts of two of grocery bags. This helps manufacturer, customer, and environmental organization decide the best type of grocery bag according certain specification of environmental awareness. In the perspective of authority, by setting policy in term of taxes or incentives, the use of any type of bags can be encouraged or discouraged.

CHAPTER 2

LITERATURE REVIEW

The study of environmental effects of grocery bags has been conducted by many organization and engineer groups because this issue is a concern to everyone. LCA is a very common method used in engineering design for environmental assessment tool. Some research paper has been studied to assist in completing this study.

2.1Comparison of existing life cycle analysis of shopping bag alternatives [2]

The research [2] was conducted to draw together existing LCA data to compare the environmental impacts of shopping bags alternatives for carrying goods in Australia. It aims to help retail decision makers and consumers choose among alternatives by informing them about the life cycle impact of alternatives to single use HDPE shopping bags and the environmentally preferred alternatives. The types of shopping bag being assessed are the common types used in Australia. The types are:

1) Single use high density polyethylene (HDPE) bag
2) Single use low density polyethylene (LDPE) bag
3) Single use Kraft paper bag
4) Single use degradable plastic bag
5) Reusable calico bag
6) Reusable non-woven (polypropylene) ‘Green Bag’

The method used in this research is the cradle to grave method which includes extraction of natural resource, production of raw material, processing, manufacturing, and fabrication of the, transportation or distribution of the product, and the disposal or recovery of the product after its useful life. Figure below shows the generic shopping bag life cycle:

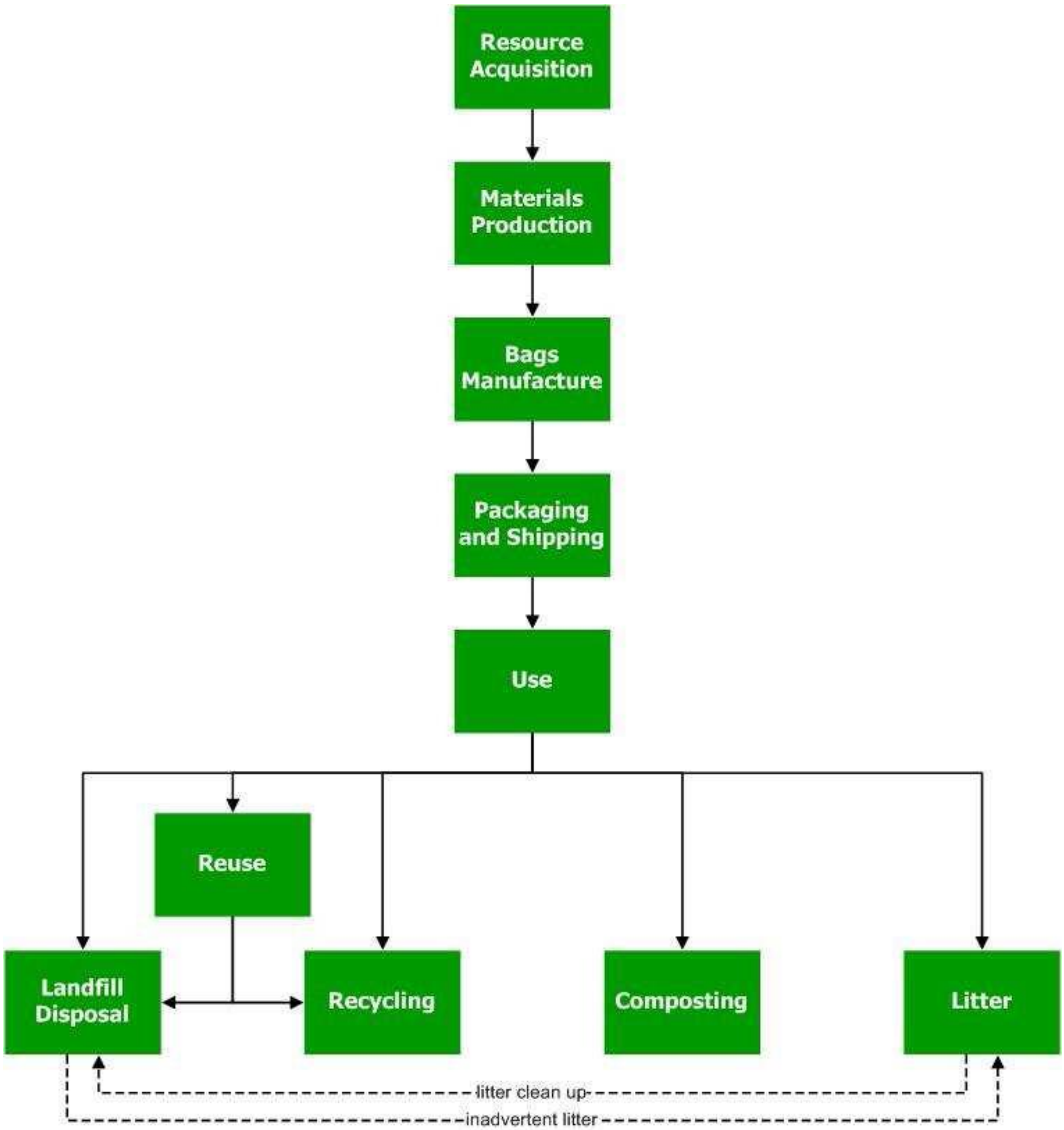

Figure 2-1: Generic life cycle of shopping bag. [2]

In this study there are several assumptions made by the author in order to complete the study. These assumptions can be referred to **Appendix 1**. The environmental impacts considered in this study are material consumption, global warming, energy consumption, water use, litter marine biodiversity, and litter aesthetic.

Some of the major findings through this study are:

1) The average household savings from switching to reusable 'Green Bags'.

2) Environmental savings from Australia switching to reusable 'Green Bags'.

3) Reusable bags have lower environmental impacts than all of the single use bags.

The detail result of this study can be referred in **Appendix 2.**

2.2 LCA of Degradable Plastic Bags [3]

The goal of the study is to understand the life cycle environmental profile of degradable plastics in the application of film blown bags and how they compare with alternative materials such as HDPE, LDPE, paper and calico.

2.2.1 Function

The function of the study is the use of shopping bags to carry groceries and goods from a store to home. The number of single use bags required and the number of reusable bags required to carry goods home per person per year were calculated. The functional unit used in this study is defined as a household carrying approximately 70 grocery items home from a supermarket each week for 52 weeks. Table 2-1 shows the characteristics of each bag in relation to the functional unit.

Degradable polymers	Use of bags					
	Weight (g)(1)	Relative capacity	Quantity of bags per week in relation to relative capacity	Expected life	Quantity of bags per year adjusted in relation to expected life	Transport to Australia (km)
Starch-PBS/A	6	1 (6-8 items)	10	Single trip	520	From Japan (8,000 km)
Starch-PBAT	6	1 (6-8 items)	10	Single trip	520	50% from Germany (16,000 km) and 50% from USA (13,000 km)
Starch-polyester	8.1	1 (6-8 items)	10	Single trip	520	From Italy (16,000 km)
Starch-PE	6	1 (6-8 items)	10	Single trip	520	From Malaysia (6,000 km)
Oxo-biodegradable bag	6	1 (6-8 items)	10	Single trip	520	Concentrate from Canada (16,000 km) and 50% of bags from Malaysia (6,000 km)
PLA	8.1	1 (6-8 items)	10	Single trip	520	50% from USA (13,000 km) and 50% from Japan (8,000 km)
Singlet HDPE	6g	1 (6-8 items)	10	Single trip	520	Hong Kong (7,000 km)
Kraft paper handled	42.6g	1	10	Single trip	520	n/a
PP fibre "Green Bag"	PP 65.6g Nylon base 50.3g	1.2	8.3	104 trips (2 years)	4.15	n/a
Woven HDPE "swag bag	130.7g	3	3.3	104 trips (2 years)	1.65	Taiwan (7,000 km)
Calico	125.4g	1.1	9.1	52 trips (1 year)	9.1	Pakistan (11,000 km)
LDPE "bag for life"	40 g	2	-	10 trips (1 year)	26	Hong Kong (7,000 km)

Note: (1) Mass of bags based upon that required so that it performs the same function as a HDPE singlet bag.

Table 2-1: Characteristics of the use of all bags [3]

Figure 2-2 shows the illustration of the system boundaries for the streamlined study. Data source used in this streamline study were from publicly available life cycle inventory data.

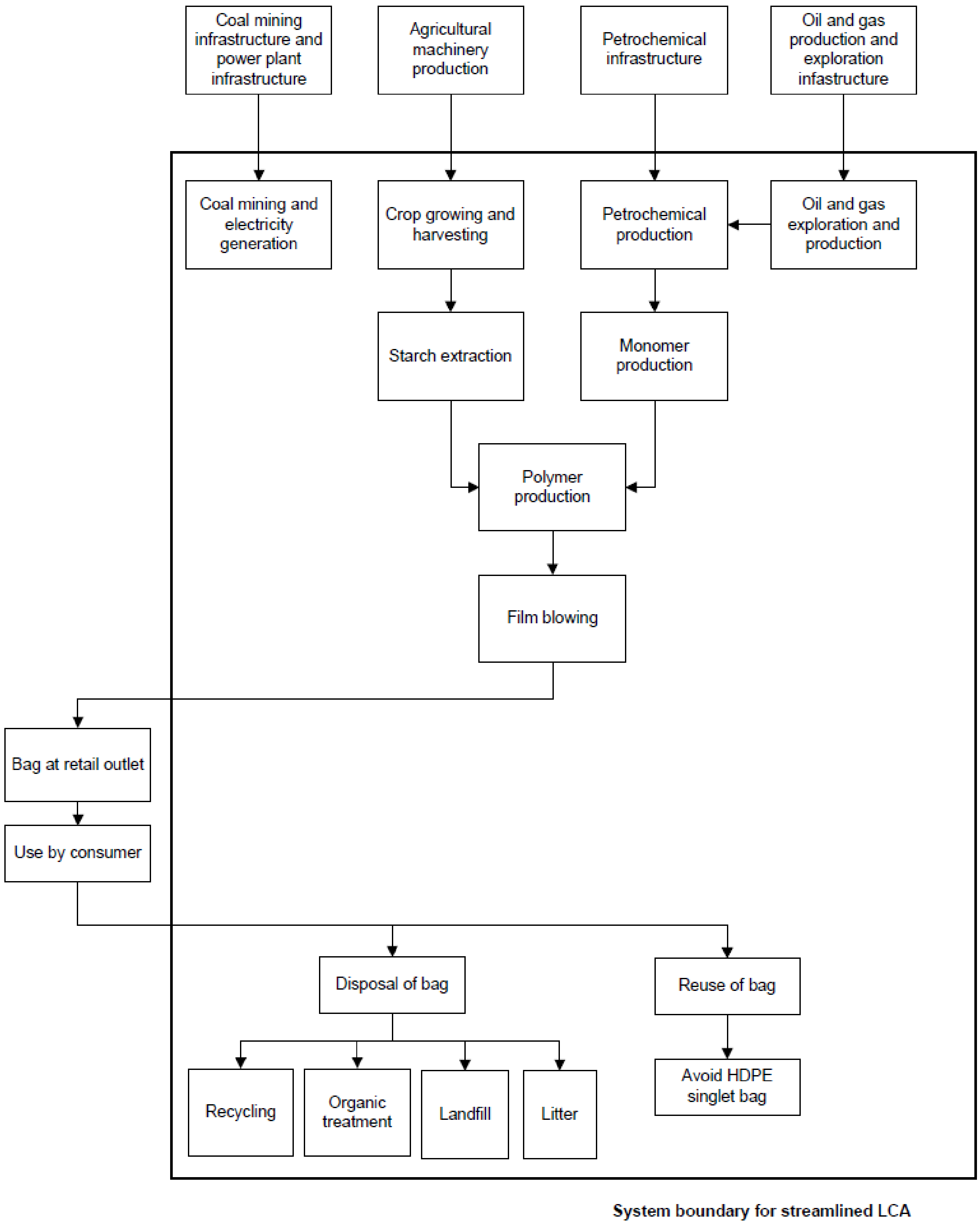

Figure 2-2: System boundary for streamlined LCA. From [3]

2.3Theory

Life cycle assessment (LCA) is a study of the environmental effects of a material or product from raw materials to the production, use and disposal of a material or product. A material or product is related to the system which is a collection of operations that together perform some defined function. An industrial system is represented by a system boundary that encloses all the operations of interest.

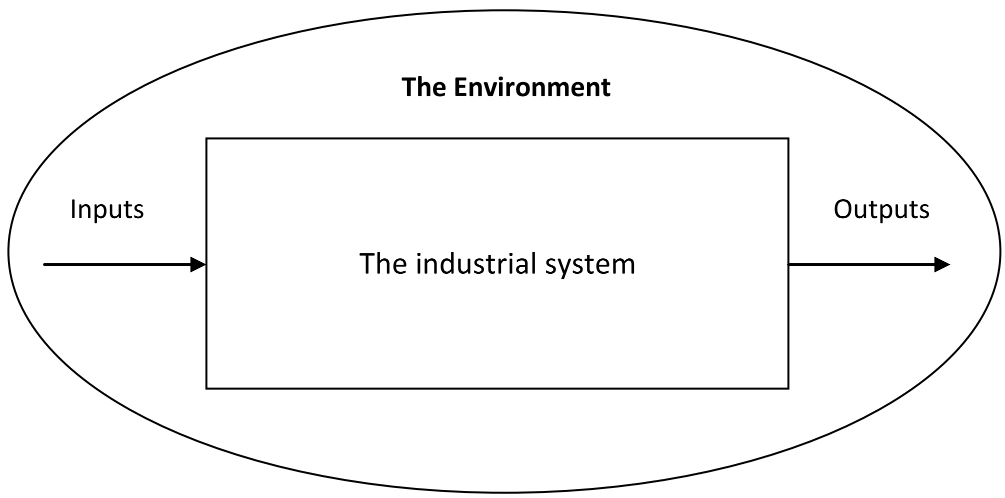

Figure 2-3: The industrial system. (Source: SETAC, 1991)

Based on Figure 2-3 the region surrounding this boundary is known as the system environment. The inputs to the system are all raw materials taken from the environment, and the outputs are waste materials released back into environment. LCA evaluates the environmental effects associated with any activity from the initial gathering of raw materials from the earth (petroleum, crops, ores, etc) to the point at which all materials are returned to the air, water, and soil. LCA is a study to comprehensively describe all these activities and the resulting environmental releases and impacts

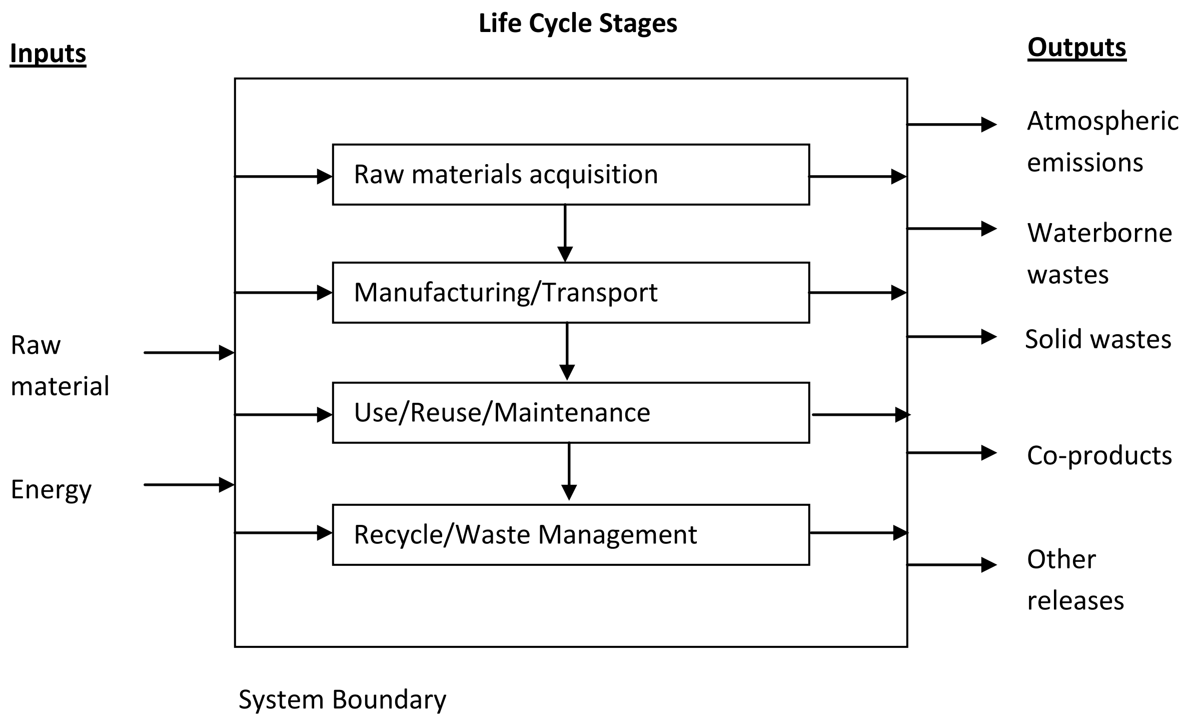

Figure 2-4: Life-cycle assessment stages and boundaries. (Source: EPA, 1993) [9]

Figure 2-4 shows the stages involved in a life cycle of a product. LCA evaluate the environmental impacts associated with a product, process, or activity by identifying and quantifying energy and materials used and wastes released to the environment. It follows the life cycle of product, process or activity from extraction of raw materials to final disposal, including manufacturing, transport, use, re-use, maintenance and recycling. However, the scopes of environmental problems cause by a product are not limited to the atmospheric emissions, the mounting problems of waste disposal, and pollution. It also concerns about the raw materials depletion, limitation of energy supply, non-renewable resources, and many more. LCA has been widely used for energy requirements calculation (energy analysis), improvement of products environmental profile, and risk assessment for industrial process.

The procedures of LCA are part of the International Organization for Standardization (ISO) 14000 environmental management standards and Society of Environmental Toxicology and Chemistry (SETAC). The ISO 14000 is a standard for environmental management systems that is applicable to any business. The objective of this standard is to reduce the environmental impacts of a business and to decrease the pollution and waste a business produces.

CHAPTER 3

METHODOLOGY

3.1 Main steps in LCA

The main tool used for this project is LCA. There are four stages involved in LCA. Figure 4 shows the steps crucial in LCA implementation.

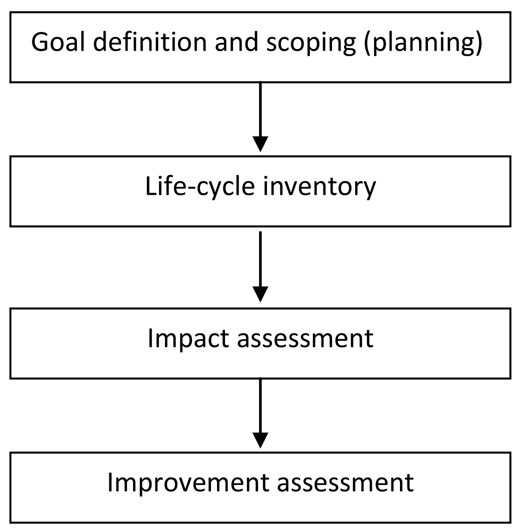

Figure 3-1: Life cycle assessment main steps.

The project is initiated with goal definition and scoping. The scope or goal of this project is to produce information for comparative study on the environmental effects. This information will be used to make decision to determine further approach whether to use alternative products or alter existing product. Several other parameters are very important for the project which is system boundaries, environmental parameters, evaluation method, and the strategy for data collection.

The second step is Life Cycle Inventory (LCI); it involves measurements, interviews, literature search, theoretical calculations, database search, and qualified guessing. There are three major types of LCI decisions: 1) allocation of inputs and outputs from an industrial operation to the various products that are produced, 2) analysis of recycling systems, and 3) reporting of energy that is embodied in products entering or exiting the LCI system.

Impact assessment stage is the interpretation of data based on the environmental impacts. It converts the results from LCI to a set of common impact measures such as excess mortality, habitat disruption, and others that allows interpretation of the total environmental effects of the system being evaluated.

The stage of the project is the improvement assessment. This stage involves decision making process through improvement priority and feasibility assessment. Sensitivity analysis also a common tool used to support decision making.

3.2 Project Flow

This project is planned to take one year period of time according to the project flow. The project flow palled is as shown below:

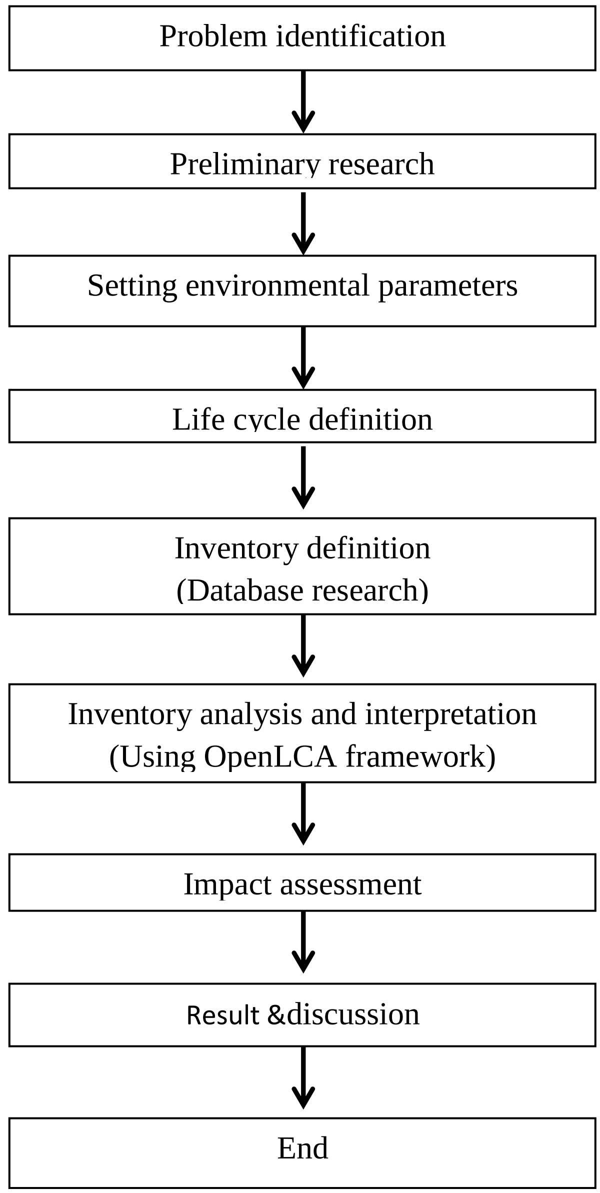

Figure 3-2: Project flowchart

3.2.1Inventory definition

Inputs and outputs of every stage are listed down to be used for analysis in the later process. Inventory definition is implemented based on Europe database referred from European Commission Joint Research Center [11].

3.2.2 Inventory analysis and interpretation

The software used for this process is OpenLCA framework downloaded from Modular Open Source Software for Sustainability Assessment website [12]. This software is applicable correspond to data documentation format of LCA under environmental management, ISO TS 14048 [13], common data exchange format for life cycle inventory data and life cycle impact assessment methods, Ecospold [14], and technical guidance documents, International Reference Life Cycle Data System (ILCD) [15].

3.3 Project planning

FYP 2 is scheduled for 14 weeks thus a project planning is conducted. Table below shows the project planning for FYP 2.

Table 3-1: Project planning

NO	**TASK/WEEK**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	**Inventory definition**	■	■	■											
2	**Inventory analysis and interpretation**				■	■	■	■							
3	**Impact assessment**								■	■	■				
4	**Result and discussion**											■	■	■	■

CHAPTER 4

RESULTS AND DISCUSSION

The products included for study are plastic bag and paper bag. The type of plastic taken into consideration is the most commonly used High Density Polyethylene (HDPE). The plastic bag manufactured from polyethylene which derived from petroleum or natural gas. This type of plastic bag is the common being used in Malaysia especially in supermarket, take-away food restaurant, and convenience store. The other type of bag is paper which made out of tree.

Types of grocery bags in this study:

1) High Density Polyethylene (HDPE) plastic bag.

- Made from polyethylene from petroleum, coal, and natural gas.
- Most common in Malaysia
- Main used in supermarket, take-away food and convenience store.
- Not biodegradable
- Normally single use but normally be reused as dustbin bag

2) Paper bag

- Made from tree.
- Only certain supermarket used paper bag.
- Biodegradable
- Normally single use
- Recycling process is available.

4.1 Functional unit

The functional unit used for this study is the quantity of bag used in a year in relation to the expected life.

Table 4-1: The functional unit for HDPE bag and paper bag

Type	Weight (g)	Relative capacity	Expected life	Transport to Malaysia	Quantity of bag per year adjusted in relation to expected life
Single use HDPE bag	6	1(6-8 items)	Single trip	n/a	520
Paper bag	42.6	1(6-8 items)	Single trip	n/a	520

Source: [3]

4.2 Environmental parameters

The environment impacts which will be core points discussed throughout this study are the common environmental impacts considered severe to Malaysia. These environmental impacts are the parameter of the study. These parameters are:

1) Global warming

2) Resource depletion

3) Energy consumption

4) Air and water pollution

   -The effect of disposal of bag to river pollution and drainage system due to clogging.

5) Landfill problem

6) Impacts on wildlife

Even though all these parameters are considered important to the environment however the perception differs according to the researchers or organizations. Some parameters are important for certain country for instance the resource depletion. The resource may be available at certain countries or otherwise. Malaysian provides their own plastic bag because we are rich the petroleum resource. This situation is different in other country because the resource is imported.

4.2.1 Global warming

Global warming is the increase in the average temperature of earths near surface air and oceans. Most of the observed temperature increase has been caused by increasing concentrations of Greenhouse Gas (GHG) for example water vapor, carbon dioxide, methane, and nitrous oxide. GHG is a gas in an atmosphere that absorbs and emits radiation within the thermal infrared range. This process is the fundamental cause of the greenhouse effect. This matter also covered by ISO 14064, it provide governments, businesses, regions, and other organizations with an integrated set of tools for programs aimed at measuring, quantifying and reducing GHG.

4.2.2 Landfill problem

It is estimated that there are about 250 landfills throughout the country. Managing them costs the governments millions of ringgit yearly. About RM 10,000 per month is needed to manage a landfill in the rural area while bigger ones in the city could cost up to RM 30,000 – RM 40,000. [16]

According to another source, a total of 17,000 tons of solid waste was produced daily and this figure rose to 19,000 tons daily by 2005. By 2020, it is estimated that 30,000 tons of solid waste will be produced daily. This staggering fact will be a big problem if not managed wisely.

4.3 Assumption

Several assumptions are made regarding the life cycle of bags in order to complete the study. The assumptions made are:

1) Transportation stage is neglected because both plastic and paper bag are made in Malaysia thus the impacts considered to be similar.

The common life cycle of grocery bag is started with the raw material acquisition, manufacturing, packaging, transportation and distribution, use, recycling, and finally disposal. Figure below shows the common life cycle of grocery bags.

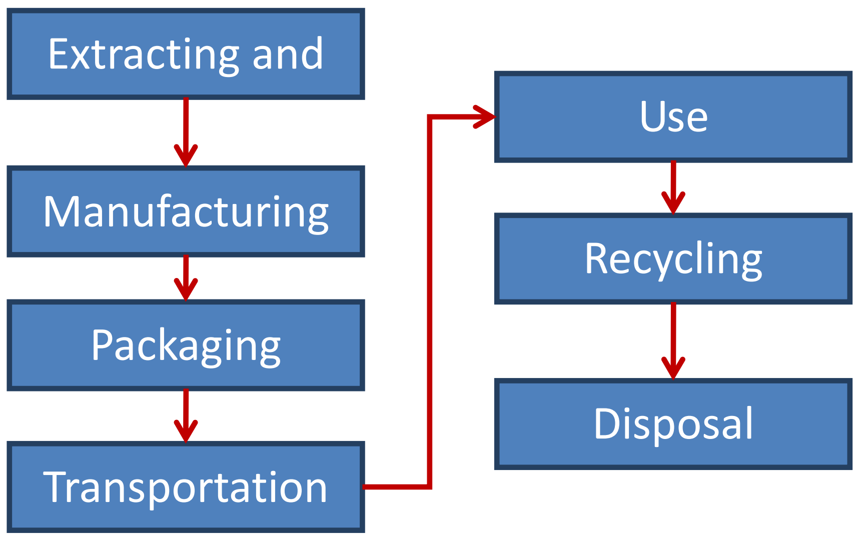

Figure 4-1: Common life cycle of grocery bag

The life cycle for different types is different and need to be studied. The first type that will be studied is the plastic bag. The life cycle of plastic bag is shown below.

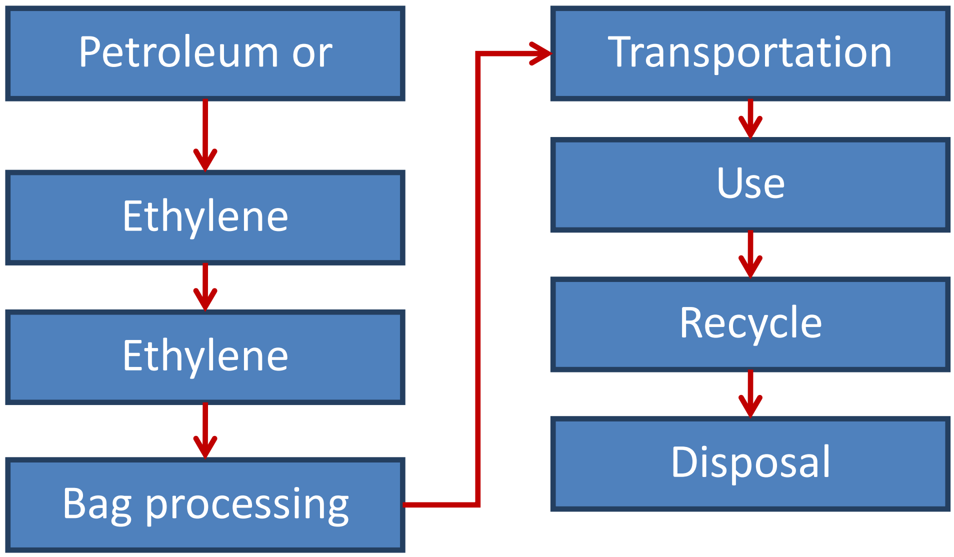

Figure 4-2: Life cycle of plastic bag

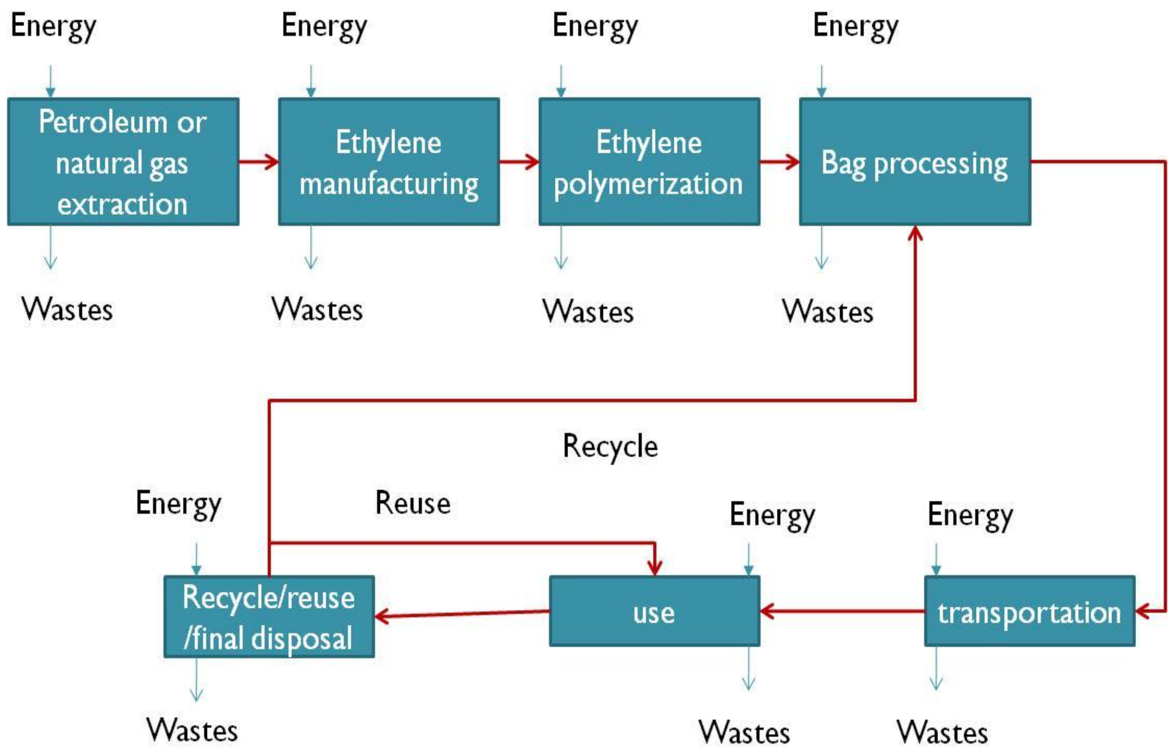

Figure 4-3: Inventory of plastic bag life cycle

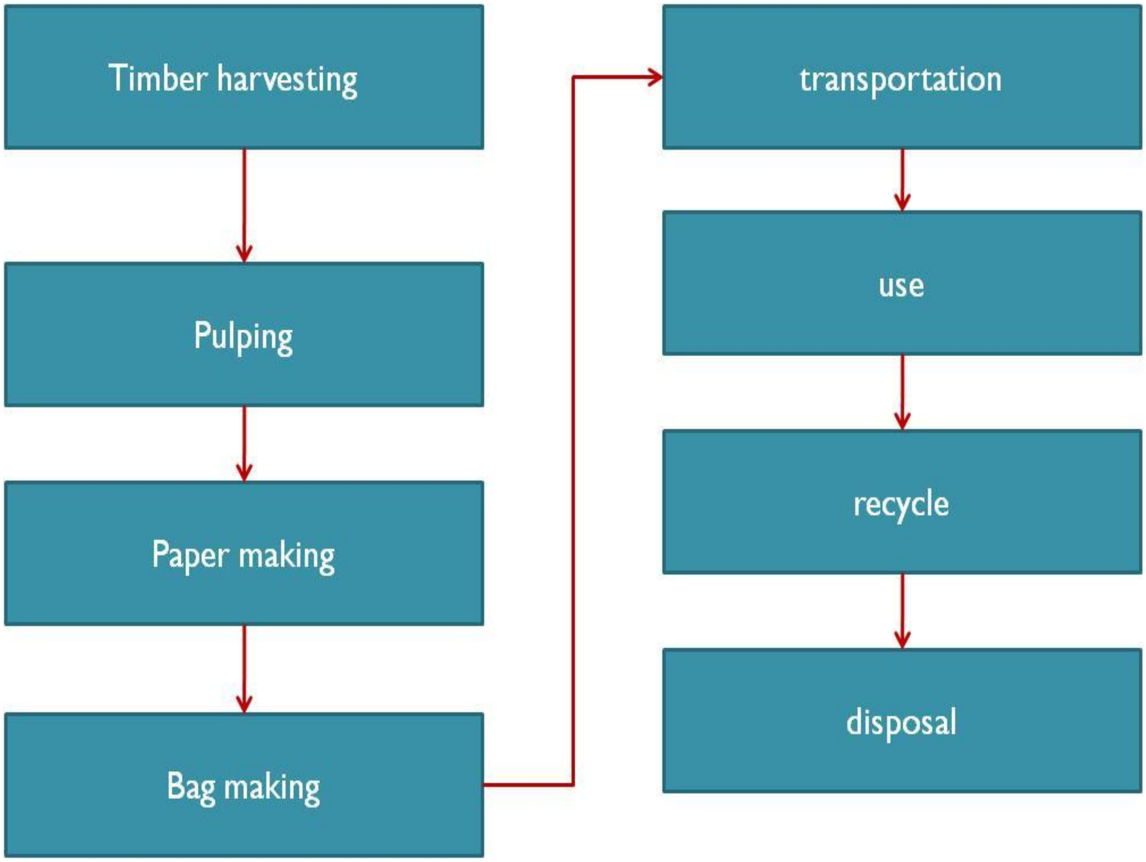

Figure 4-4: Life cycle of paper bag

4.4 Impact assessment

The impacts are then analyzed based on the environmental parameter set earlier in this study.

4.4.1 Global warming

The major emissions that contribute to global warming are the greenhouse gas. The most abundant greenhouse gases are water vapor, carbon dioxide, methane, nitrous oxide, ozone, and chlorofluorocarbons. Based on all the data available the global warming impact is analyzed for both type of bag. The data collected from the production of plastic bag and paper bag.

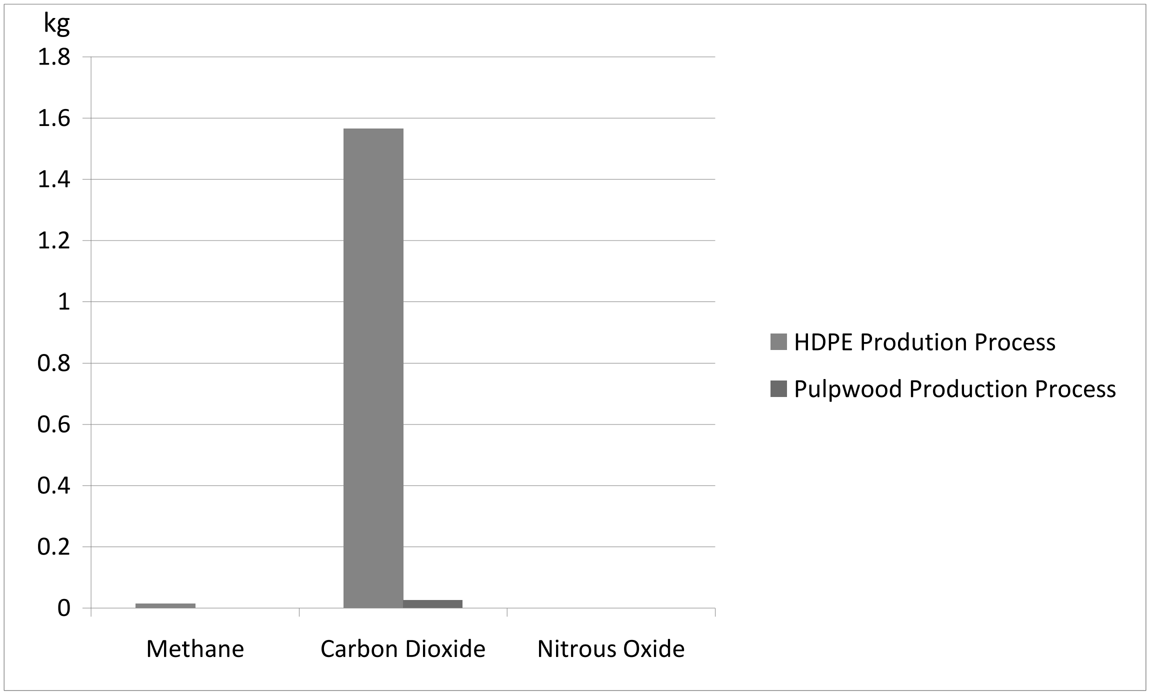

Figure 4-5: Greenhouse gas emission from plastic and paper production

Table 4-2: Greenhouse gas emission comparison

Emission	**HDPE Production Process**	**Pulpwood Production Process**
Methane	0.0142 kg	4.0429E-5 kg
Nitrous Oxide	7.9135E-13 kg	5.0742E-7 kg
Carbon Dioxide	1.5668 kg	0.0255 kg

Based on database available the HDPE production process emits more greenhouses gases compared to the pulpwood process. Methane gas is a relatively potent greenhouse gas with high global warming potential of 72 (calculated over a period of 20 years) and also can affects the degradation of the ozone layer. HDPE process produces about 300 times the amount of pulpwood processing. Carbon dioxide released from HDPE process is 60 times larger than the release from pulpwood process.

4.4.2 Resource depletion

This parameter focuses more on the main raw material and also the non-renewable resource used in the production process of grocery bags.

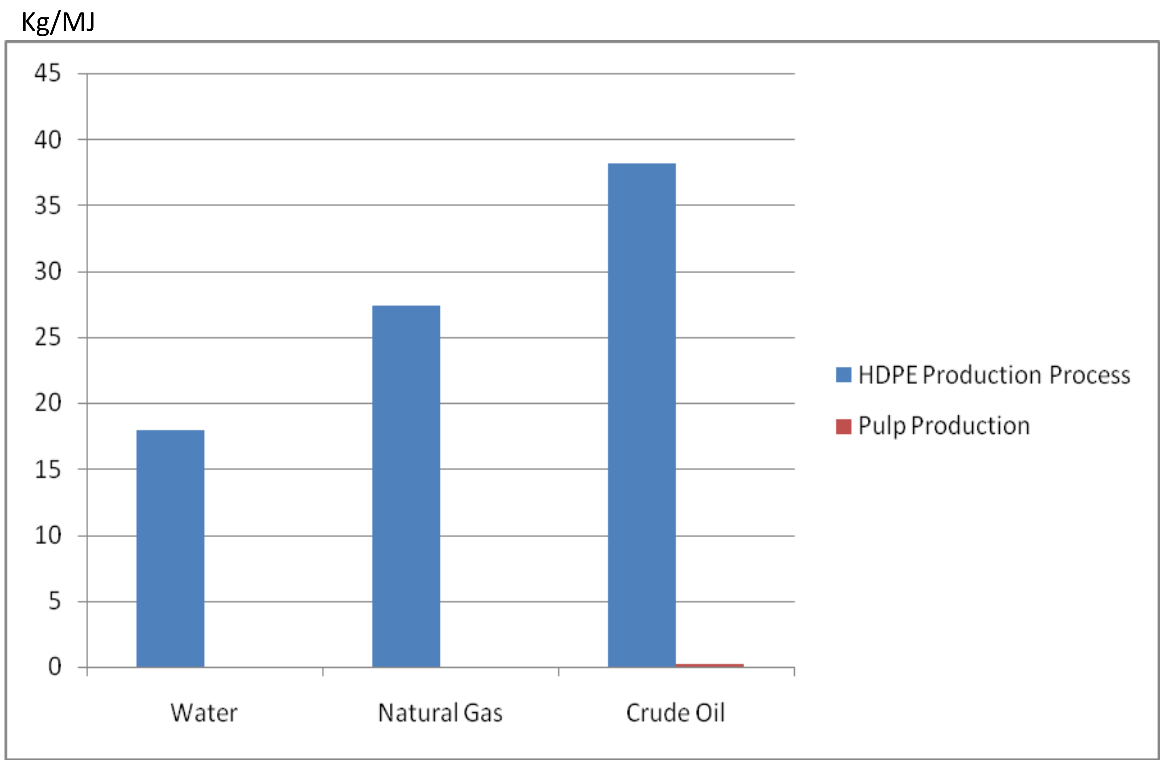

Figure 4-6 : Resource depletion from HDPE production process and pulp production process

Table 4-3: Resource depletion comparison

Resource	HDPE Production Process	Pulpwood Production Process
Water	17.905 kg	1.6158E-4 kg
Natural Gas	27.400 MJ	0.0327836 MJ
Crude Oil	38.149 MJ	0.1969 MJ

It is obvious that HDPE production process uses up much larger resource like crude oil, water, and natural gas for the production process. HDPE uses more non-renewable source compared to paper.

4.4.3 Energy consumption

For energy consumption analysis the energy analyzed is based on the main generator of based on database information. This includes primary energy from hydro power, geothermic, solar, and wind. The comparison of energy consumption for both grocery bags is as shown below:

Table 4-4: Energy consumption comparison for HDPE production process and pulpwood production process.

Energy source	**HDPE Production Process (MJ)**	**Pulpwood Production Process (MJ)**
Hydro power	0.5832	0.0048
Geothermic	0.0273	7.092E-6
Solar	1.040E-4	10.44
Wind	0.0159	0.0053

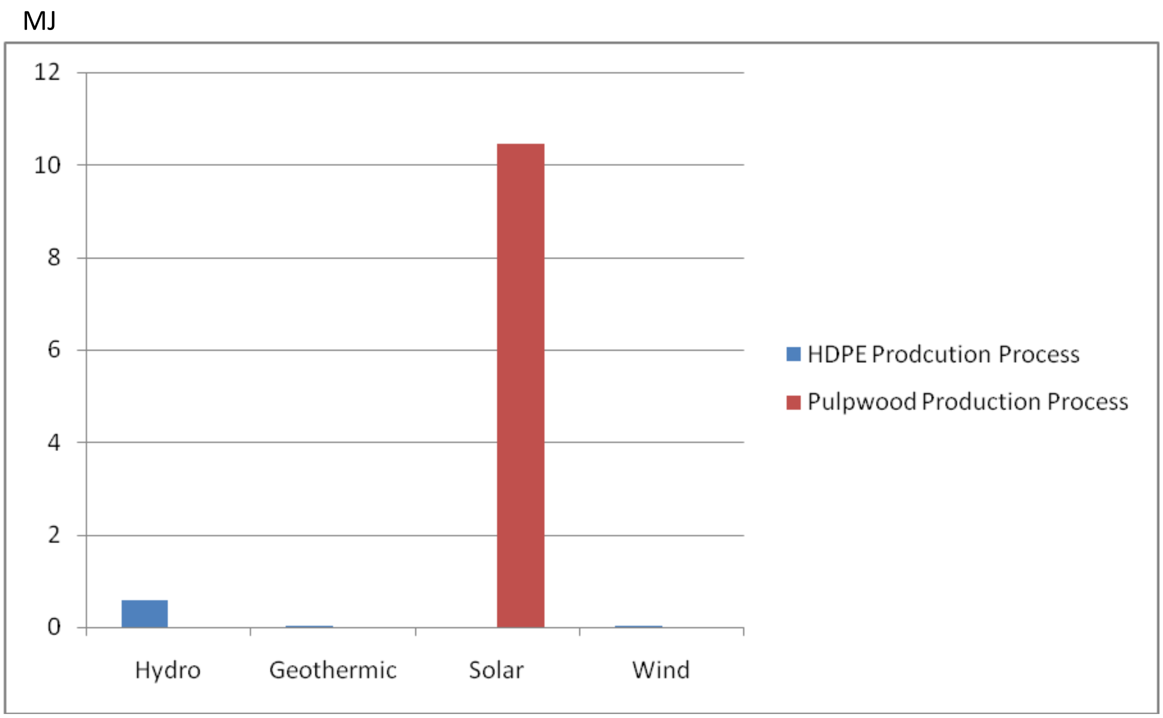

Figure 4-7: Energy consumption comparison between HDPE production process and pulpwood production process

4.4.4 Landfill problem

Based on the functional unit used in the study paper bag contribute more weight compared to plastic bag with 6 g and 42.6 g respectively. This indicates paper bag will takes more volume compare to plastic bag however the other important thing which need be discussed is the biodegradability of the material. With the assumption of recycling rate at around 3% based on recycling rate in Malaysia almost all the grocery bag will go to landfill for waste management. [17]

Despite the biodegradable characteristic of paper, paper bags usually will not biodegradable for much faster than plastic bag because the environment at landfill tends to slow the biodegradation process due to lack of oxygen, water, light, and other important elements necessary for the degradation process to occur.

4.4.5 Impact on wildlife and the effect of bags to river clogging

Littered grocery bags at especially river and sea may have cause death to aquatic wildlife. This can be caused by the animal choked because mistaken bags as food. This is influenced by the biodegradable characteristic of the bags and also the time elapsed for bags to sink. Table below shows the assumptions made for both bags.

Table 4-6: Litter marine biodiversity of grocery bags

Types of bag	**Litter marine biodiversity**
HDPE	Float for 6 months
Paper	Assume to sink in 1 day

Source: [10]

Based on the assumptions, paper bag tend to sink much earlier and also biodegradable faster in water which means it does not cause river clogging and also less likely to harm aquatic wildlife.

4.5 Discussion

HDPE contribute a big impact on global warming due to high carbon dioxide emission. In term of resource depletion, HDPE also uses more resource than paper bag however the resource used by paper bag is different. The study is based on the no renewable resource. Paper bag consumes more energy than HDPE due to the pulping process. Paper bags have a bigger impact on landfill problem compared to HDPE bag due to the high volume. Plastic bag has caused harm to wildlife and also river/drain clogging due to litter marine biodiversity characteristic.

CHAPTER 5

CONCLUSION

Based on the analysis, HDPE bag contributes a big impact on global warming due to high greenhouse gas emission from HDPE production process. HDPE bag also uses more non-renewable resource compared to paper bag. Paper bag consumes more energy compared to plastic bags form the paper production process and also it has a bigger impact on landfill problem. A paper bag weigh 8 times more than a plastic bag thus contributes to heavier solid waste. Even though paper bag material is biodegradable, degradation does not occur as fast as people think it is at landfill. The process is slow because of lack of degradation agent like oxygen, water, light, and other important element. With high weight of solid waste paper bag causes bigger impact on landfill problem than plastic bag.

Other important impacts are the cause toward wildlife and litter aesthetic. Most of grocery bags used in Malaysia are plastic bag and most of them end up littered and disposed. The littered bags cause harm to aquatic life and also causes river clogging. Plastic bag has high possibility to cause these two impacts because of its non-biodegradable characteristic and according to study it will float for 6 months compared 1 day for paper bag.

In Malaysia, plastic bag has been the most common grocery bag used thus decreasing the number of disposed plastic bag will be the most appropriate way to reduce environmental impacts. By introducing recycle, reuse, and reduce (3R) concept to the society, the plastic bag taken at supermarket everyday can be put to good use. The solution is not about banning the use of plastic bag but encourage people to think about what they do with the bags after they use them.

In the perspective of authority, including taxes or price for every plastic bag handed out at supermarket and encourage people to bring their own bag are good idea to reduce bag consumption. The taxes collected can be used for other beneficial activities. For instance, a tax on shopping bags in the Republic of Ireland has cut their use by more than 90% and raised millions of Euros in revenue, the government says.

On the other hand, manufacturers of grocery bags should look into other alternatives like introducing corn starch bag which is more environmental friendly, introducing additive into plastic to increase the biodegradability, and introducing woven bag which last longer and highly reusable. The alternatives should focus on the resource use, environmental impact from the production processes, and biodegradability.

In conclusion, this project gives a new insight on the environmental impacts of a product. This approach can be used to analyze environmental profile of other product and should be implemented corresponding to the green technology design approach in products nowadays.

5.1 Recommendation

The study could use some other aspects:

1) Use database from Malaysia.

2) Uses more accurate data rather than assumptions.

3) Propose a study on other alternative bags which has already widely used today.

4) Use LCA software for further understanding of the study.

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APPENDICES

Appendix 1

Data on bag types relates to the most prominent example of each bag already in use in the Australian retail market.

To allow for size differences in bags, the assessment takes into account relative carrying capacity and expected life.

The assessment also takes into account any avoided impacts such as:

- Avoided use of virgin polymer or paper fibre due to bag recycling programs
- Avoided consumption of kitchen tidy bags as a result of bag reuse in the home.

Whenever possible, data is based on actual bag use acknowledging that there is variability of each bag type in the marketplace.

Although relevant to all retail applications, the assessment is based on an application for supermarket use.

Alternative have been modeled assuming 52 shopping trips per year with 10 average plastic shopping bag loads each trip.

The manufacturing assessment of each shopping bag included the extraction of raw materials and the processing of them into the final product. For imported bags, overseas inventory data specific to the country of origin was used where possible.

The transportation of each shopping bag was factored into the LCA. This included the international shipping of imported bags to Australia. For internal transportation to retailers, a distance of 115 km in a 28 tonne articulated truck was used for all bag alternatives.

No allowance has been made for maintenance of bags (washing and ironing) during the use stage.

Due to the variance in materials and expected life of many of the shopping bag alternatives, a number of end-of-life assumptions were factored into the LCA. It should be noted that the analysis is highly dependent on assumptions made about reuse of bags; use patterns of reusable bags; percentage of bags entering the litter stream.

Data on biodegradable plastic bags is the least reliable of all inventory data used in the analysis, as very little LCA work has been done on starch based plastics to date. It should therefore be treated with particular caution.

Appendix 2

Table 4-4 Environmental impacts of single use HDPE shopping bags and their potential alternatives over the full life cycle of the bag

Bag type	Example	Material consumption (kg)	Global warming (kg CO_2 eq)	Energy consumption (MJ)	Water use (kL H_2O)	Litter marine biodiversity (kg.y)	Litter aesthetics (m^2.y)	Disposal options
Reusable non-woven plastic (polypropylene) "Green Bag"		♠	♠	♠	♠	♠	♠	Recycle at major supermarkets
Reusable calico bag		♠	♠	♠	♠♠♠♠♠	♠	♠	No recycling, dispose to landfill
Reusable kraft paper bag with 100% recycled content (2 trips)	Photo unavailable	♠♠♠♠♠	♠♠♠	♠♠	♠	♠	♠	Recycle in household recycling bin
Single use oxo-biodegradable bag (e.g. TDPA-EPI)		♠♠♠	♠♠	♠♠♠	♠	♠♠♠	♠♠	Reuse as a garbage bin liner (disintegrates over several years)
Single use plastic (HDPE) bag with 100% recycled content		♠♠♠	♠	♠	♠♠	♠♠♠♠♠	♠♠♠♠♠	Recycle at major supermarkets Reuse as a garbage bin liner

Bag type	Example	Material consumption (kg)	Global warming (kg CO_2 eq)	Energy consumption (MJ)	Water use (kL H_2O)	Litter marine biodiversity (kg.y)	Litter aesthetics (m^2.y)	Disposal options
Reusable kraft paper bag (2 trips)		♠♠♠♠♠	♠♠♠♠	♠♠♠	♠	♠	♠	Recycle in household recycling bin
Single use compostable starch-polyester blend bag (e.g. Mater-Bi)	Photo unavailable	♠♠♠♠	♠	♠	♠♠♠♠♠	♠	♠♠	Compost (degrades within six months) Reuse as a garbage bin liner
Single use plastic (HDPE) bag		♠♠♠	♠♠	♠♠♠♠	♠	♠♠♠♠♠	♠♠♠♠♠	Recycle at major supermarkets Reuse as a garbage bin liner
Single use kraft paper bag with 100% recycled content	Photo unavailable	♠♠♠♠♠	♠♠♠♠♠	♠♠♠♠	♠	♠	♠♠	Recycle in household recycling bin
Single use kraft paper bag		♠♠♠♠♠	♠♠♠♠♠	♠♠♠♠♠	♠♠	♠	♠♠	Recycle in household recycling bin
Single use 'boutique' plastic (LDPE) bag		♠♠♠♠♠	♠♠♠♠♠	♠♠♠♠♠	♠	♠♠♠♠♠	♠♠♠♠♠	No recycling, reuse as a garbage bin liner

Figure A-1: Result of literature review

The following table summarizes the findings of the LCA of shopping bags alternatives. A rating of one to five was used to show the diversity of impacts for each criterion, with one being the lowest impact. In some cases at the high impact end, the impact value of the bag fell outside the rating scale. Impacts cannot be added together to produce an overall bag rating.