Life Cycle Assessment of
Plastic Bag Production

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Abstract: The main focus of this report is to establish a comparative study of traditional and biodegradable vest-plastic bag production through the utilization of a life cycle assessment (LCA) approach. The measurements were made for the Ukrainian limited liability company “Polymer”, as a representative manufacturer, in order to calculate the environmental impact of plastic bag manufacturing, and identify the more environmental friendly item.

This research is based on a literature review of the special characteristics of life cycle assessment and its methods and methodologies, a field study, which included two semi-structure interviews, and measurements and comparison of the harmfulness of traditional and biodegradable bag production. The software SimaPro 7.3.2 and IMACT 2002+ method were chosen in order to accomplish the research purpose.

The results of the study show that traditional vest-bags produced by the researched enterprise are less environmentally friendly. Their production process has a bigger impact on environment and human health than that of the biodegradable bags. Moreover, a list of recommendations for possible improvements was developed based on the results of the research. It was sent to the directors of LLC “Polymer” as a suggestion for creating a “green strategy” of further development.

Keywords: life cycle assessment, environmental impact, sustainable development, plastic bag production, SimaPro 7.3.2 software, IMPACT 2002+ method.

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Summary: Our world met different environmental problems during last several centuries, which are mostly caused by humans' activities. Climate change, melting of glaciers, depletion of the Ozone layer, deforestation, decreasing nonrenewable resources, degradation of soils, loss of biodiversity, water pollution and many others have had an important impact on humans life. We should find ways to solve or diminish these problems not only because of our life dependency on conditions and quality of the environment, but also for moral issues and reasons of responsibility for our descendants. The difficulty is that we have created so many artificial and chemically complicated substances, which don't have analogies in the nature. These materials are dangerous because we have no idea about their degradation period or influence on living beings. Plastic is an example of such material. Unfortunately, it is widely used all around the world, because of useful characterize for people.

The main focus of this report is to establish a comparative study of traditional and biodegradable vest-plastic bag production through the utilization of a life cycle assessment approach. It is "a standardized method, that has a clear focus on the function for the user of the product or service, with the intention of minimizing total impact on the environment occurring as a result of fulfilling this function" (Askham 2011, p.43). The measurements were made for the Ukrainian limited liability company "Polymer", as a representative manufacturer, in order to calculate the environmental impact of plastic bag manufacturing, and identify the more environmental friendly item. Moreover, the final result is a list of first recommendations for the research enterprise for getting ISO 14 00x certificate in future.

This research is based on a literature review of the special characteristics of life cycle assessment and its methods and methodologies, a field study, which included two semi-structure interviews, and measurements and comparison of the harmfulness of traditional and biodegradable bag production. The software SimaPro 7.3.2 was used in order to accomplish the research purpose. This software helps to create models of product systems, which are based on transparency and logic (Goedkoop *et al.* 2010). Moreover, this software helps to create models of product systems. It includes several methods for measuring environmental impact, but for my study I used IMPACT 2002+. It is a combined method, which has 15 categories of the midpoint and 4 categories of endpoint (Jolliet *et. al*, 2003).

The results of the study show that traditional vest-bags produced by the researched enterprise are less environmentally friendly. Their production process has a bigger impact on environment and human health than that of the biodegradable bags. Moreover, a list of recommendations for possible improvements was developed based on the results of the research. It was sent to the directors of LLC "Polymer" as a suggestion for creating a "green strategy" of further development.

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Contents

List of Acronyms

FU	Functional unit
HDPE	High-density polyethylene
ISO	International Organization for Standardization
LCA	Life cycle assessment
LDPE	Low-density polyethylene
LLC	Limited liability company
PE	Polyethylene
PET	Polyethylene terephthalate
SD	Sustainable development

1. Introduction

During the 20th century humanity encountered numerous environmental challenges and problems. Climate change, melting of glaciers, depletion of the Ozone layer, deforestation, decreasing nonrenewable resources, degradation of soils, loss of biodiversity, water pollution and many others have had an important impact on modern life. We should find ways to solve or diminish these problems not only because of our life dependency on conditions and quality of the environment, but also for moral issues and reasons of responsibility for our descendants. The Earth is over polluted and thousands of hectares of valuable land are covered by waste while even the oceans have actual islands of plastic bottles and other harmful materials. The “Great Garbage Patch” in the Pacific is two times bigger than Texas State (Alleyne 2011). Only a small amount of phytoplankton and few fishes can be found there. Such an environmental situation shows that there is no sustainable usage of recourses and energy in the world.

In addition, scientists have created a vast variety of artificial materials and chemical substances, which do not have natural analogies. For this reason it’s especially difficult to make predictions about the degradation effects and the influence these substances will have on aquatic or terrestrial ecosystems. The impact of plastic on terrestrial ecosystems is the topic of this thesis. Plastic is a material which is made from oil, natural gas or their by-products utilizing, different technological processes.

Today plastics have replaced many natural materials because of their specific characteristics, such as being lightweight, insulating, durable, elastic, cost efficient, etc. Plastics are used for covering technical equipment and cables, packaging products and materials, carrying goods, construction and so forth. Almost everyone on the planet uses plastic bags every day, as they are mostly free of charge at the supermarket cash-desks. Modern city landscapes have changed recently as “bags are often entangled on fences, in trees or in waterways, where they can threaten aquatic life, and interfere with visual aesthetic of the natural environment” (Horne *et al.* 2009, p.67).

Although plastics provide humans with many advantages they play an opposite role for the environment. For example, plastic bags are dangerous for wildlife as animals can eat them and then die from intestinal blockages. Even after the animal’s death and body decomposition, the plastic bag will remain. Small birds can be covered by plastic bags and suffocate. Also, bags can be barriers for drainage system and waterways, which can destroy natural ecosystems. In addition, plastic bags contribute to human dependence on oil, as it is the main raw material in plastics manufacturing. Even, if all these drawbacks are known, plastic bags are still produced and used in huge amounts.

Many studies have been made on the question of the environmental impact of lightweight carrying bags in the context of developed countries: Sweden, the USA, the UK, Australia, Germany etc. Comparisons of paper, plastic and calico bags have been studied in order to find the best environmentally friendly option for customers and producers. Moreover, “the awareness and interest of decision makers in many countries has grown and a wide variety of policy instruments are being implemented in different places to decrease the scale of the problem” (Ayalon *et at.* 2009, p. 2025). Unfortunately, in developing countries the problem of plastic bags is not a topic of public discussion or scientific research, because of political and economical instability and low environmental education of the population.

1.1. Purpose and Research Questions

The purpose of this thesis is to perform the life cycle assessment of plastic bag production, using a specific case in order to measure the impact of the manufacturing process on environmental and human health and identify which type of plastic bag is the most environmental friendly. To fulfill this purpose, I (1) reviewed international research on life cycle assessment of production systems and methods of plastic bag production, (2) performed a field study, which included holding two semi-structured interviews, (3) collected data on plastic bag production at the limited liability company (LLC) "Polymer" in Ukraine, (4) measured environmental impact of plastic traditional and biodegradable bag production using SimaPro 7.3.2. software, (5) performed an analysis of assessment results and drew conclusions about the most sustainable type of bags among the analyzed production systems.

The main aim of this research is to present recommendations for the possible implementation of an environmental management system for the enterprise, which could be a very first step for improving the manufacturing process and focusing on getting LLC "Polymer" ISO 1400x certification in future.

1.2. Methodology

This research is based on literature review of the life cycle assessment approach and its different methods and methodologies, a field study, and measurements of the harmfulness of plastic bags manufacturing process by using particular software.

Life cycle assessment is an analytical approach that helps to calculate the harmfulness of the whole production process for environment and human life. Specific software products are created to do that. I chose SimaPro 7.3.2 software for my studies, because I had had an experience of working with it before. Moreover, this software helps to create models of product systems, which are based on transparency and logic (Goedkoop *et al.* 2010). It includes several methods for measuring environmental impact, but for my study I used IMPACT 2002+. It is a combined method, which has 15 categories of the midpoint and 4 categories of endpoint (Jolliet *et. al*, 2003).

All information and data were collected during two semi-structured interviews in December 2011 and February 2012. As I had an internship at the LLC "Polymer" I was quite aware about the technological process, but I wanted to research a particular case, which required specific information and data. That is why I have made several visits to the enterprise. The first appointment with quality manager, Mykola Lubenko, was at the beginning of December in the year 2011. He provided me with basic information about industrial process, materials, resources, emissions and pollutions. It was a start point of the practical part of my thesis. The outline of the interview is in the Appendix A. It includes a list of focus points and main questions, although I asked many more questions during the excursion at the enterprise. Yet, during further calculations I figured out that this information is not enough to measure the environmental impact of the manufacturing process of plastic bags. That is why in February 2012 I had a second appointment with Vitalij Klischuk, a main engineer, who is also responsible for environmental issues at the LLC "Polymer". This time it was a more specific interview, as I had been already working with calculations and requested particular information. The questionnaire is presented in Appendix B. Luckily I got all the necessary data and was ready for the measurement of life cycle after these interviews.

1.3. Ukrainian case study

After general overview of the research topic, I started to identify gaps in this field for further exploration and research. Developed countries have already done a lot in this sphere (Statyukha *et al.* 2009), so the focus was shifted to less developed countries and situation there. As I'm originally from Ukraine, a country with a transition economy, I decided to base my investigation on the Ukrainian experience. The limited liability company "Polymer" was chosen as case study among all plastic manufactures in Ukraine, because of several reasons: firstly, I had had an internship at the Quality department during two months in 2009 and have personal contacts there; secondly, the enterprise is in the rank of top-100 companies in the Vinnitsa region now with significant capacity and production. According to the information on the company's web-site, it has developed from a small enterprise, which produced copybook covers, to a big company with plans for further development. The goal of their work is to provide consumers with all kinds of flexible packaging with high quality and consumer value (LLC "Polymer" 2012). They are open to implementing new technologies and improving the manufacturing process. Every year they participate in the international conferences and exhibitions all around the world. It is important for collecting information about novelties and improvements in this sphere, and meeting new partners and customers. Finally, the staff is ready to work with students and share information and data for bachelor and master theses, as they see it as an opportunity to improve the production process and find well qualified workers.

2. Conceptual Framework: Life Cycle Assessment

Life cycle assessment is one of the main tools which are commonly used around the world, because it helps to measure energy, water and other resources usage, pollution emissions to the air, water and soil, wastes disposal and other negative effects of the manufacturing process. Moreover, it's based on a "cradle-to-grave" concept, which means that all stages from extraction of the raw materials till wastes disposal or reuse can be included in the analysis. There are many definitions of life cycle assessment. Until now there has been a discussion between scientists as to whether it is a method, approach or a technique. "Life cycle assessment is "a standardized method, that has a clear focus on the function for the user of the product or service, with the intention of minimizing total impact on the environment occurring as a result of fulfilling this function" (Askham 2011, p.43). According to ISO 14040:2006 "LCA is a technique for assessing the environmental aspects and potential impacts associated with a product by:

- compiling an inventory of relevant inputs and outputs of a product system.
- evaluating the potential environmental impacts associated with those inputs and outputs.
- interpreting the results of the inventory analysis and impact assessment phases in relation to the objectives of the study".

Life cycle assessment is used for monitoring and measuring the impact of industrial processes on environment and human health. Today this method is quite common and widely used, because its models show the complex relationship between production and the environment. A single methodology for life cycle assessment, which is accepted all around the world, has not been developed yet (Zbicinski *et al.* 2006). It is a fairly new approach, which gained popularity around the world and worked properly only since the early 90^{s} (Haes and Heijungs 2007). It has transformed into a tool of material and energy flows' identification and impacts association. The first idea was emerged in the late 60s in the United Stated of America (Hauschild 2007). The Coca-Cola LCA study in 1969-1970 is considered the first example, which was made by the Midwest Research Institute in the USA (Baumann and Tillman 2004). However, after the Club of Rome published the report "Limits to Growth" and the oil crisis in 1972, life cycle assessment gained a huge popularity in Europe.

In the 70s Great Britain, Switzerland, Sweden and the USA were working on developing methods and models for calculating the environmental impact of product life cycles. Unfortunately, in the 80's this approach was forgotten for a while. But in the 90s different scientific groups returned to actively exploring this direction, due to the awareness of natural resource limitations and the extent of the destructive consequences of environmental problems (Hauschild 2006). The results of LCA can be useful for design; environmental, water and waste management; different political agreements; supporting the environmental legislation and regulation; developing criteria for environmental taxes, standards or environmental labeling programs; or providing consumers with information, and so on. In addition, "decision-making is central to life cycle assessment, both in the sense that LCA may be used as decision support and in the sense that different methodological choices in LCA are relevant to different applications" (Tillman 2000, p.113).

The International Organization for Standardization (ISO) developed several certificates responsible for life cycle assessment, such as ISO 14040 (Environmental management - Life cycle assessment – Principles and framework), ISO 14041 (Environmental management - Life cycle assessment – Coal and scope definition and inventory analysis), ISO 14042 (Environmental management - Life cycle assessment – Life cycle impact assessment) and ISO 14043(Environmental management - Life cycle assessment – Life cycle interpretation) (ISO 14049, 2000). Their main focus is implementing environmental management within the firm, enterprise or company, through using LCA as a technical tool for calculation issues. "These standards primarily pertain to process requirements such as necessary documentation rather than model requirements" (Hendrikson *et al.* 2006).

Product life cycle includes all the "inputs" (raw materials and energy), and "outputs" (emissions to the air and water, by-products and wastes disposal). In the industrial ecology this approach is called "method of thinking manufactures ecology" (Rebitzer *et al*. 2004, p.703), as it can measure all stages of the production process. Usually researchers follow a specific structure of life cycle assessment, which includes four main steps (ISO 2006):

- *Goal definition and scoping.* In other words it is a stage of planning, setting goals, objectives and limits of the system. It is a fact that narrowing of research questions can lead to unreasonable simplifications, uncertainty and mistakes, but on the other hand it is impossible to include everything in the research. It's important to determine a functional unit (FU) – "the measure of performance which the system delivers" (Zbicinski et al. 2006, p.92). System boundaries should also be identified as well, which show the start and the end point of the research process, the number of stages, depth of analysis, time and geographic scope.
- *Inventory analysis.* This phase involves building a production flowchart according to the goal and system boundaries, collecting data and necessary information, checking the flow of inputs and outputs of materials and energy and doing basic calculations.
- *Impact Assessment.* This stage links the results of environmental impact inventory and their evaluation. The methodological framework for this phase requires revision and development, as currently there are no generally accepted and ideal methodologies.

- *Interpretation.* This step involves presenting the results, writing recommendations and solutions for decision makers. The result is compared with the initial goal and conducted with sensitivity and uncertainty analysis.

The graphical visualization of four stages of life cycle assessment is presented on the Figure 1 below.

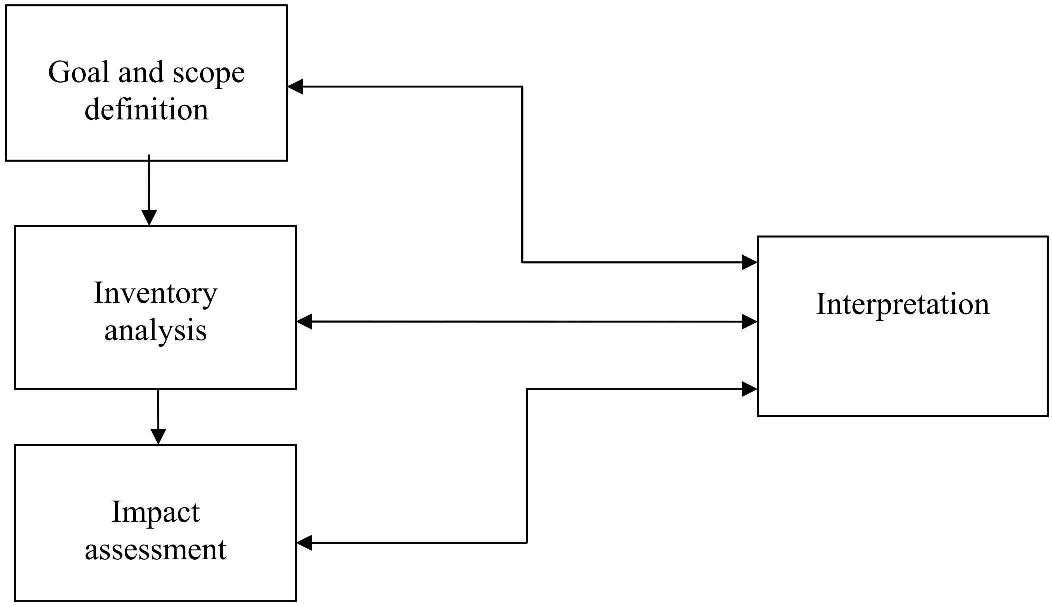

Figure 1. Outline of generic life cycle assessment process (Horne et al. 2009).

The third step, impact assessment, has three mandatory phases (categorization, classification and characterization) and four optional phases (normalization, grouping of related account, sorting and weighing of impacts). All of them include specific calculations and assessments.

Categorization involves selection categories that relate to the scope and purpose of the research. These categories may be global warming, eutrophication, land use, human toxicity, ozone depletion, depletion of natural resources, biodiversity and many others. It is a fact that "the choice of impact categories is subjective" (Zbicinski et al. 2006, p.97). *Classification* is a stage of attributing categories according to their influence. *Characterization* is a stage at which each substance or material is attributed to the potential impact of a particular category. There are two types of characterization categories: the middle- and end-point. For calculations it is necessary to clearly establish the boundary between the economic system and the environment, because sometimes the interrelation can be very close.

Normalization is an optional life cycle assessment stage, which helps to understand clearly the impact of toxic emissions on environmental and human health. There is no particular scheme for normalization, as each country tries to explore the experience of the others and adapt their methods to their own conditions and needs. It is a fact, that the results of normalization have the same measurement units in every category, which makes it easy to compare different impact categories. Normalization step can represent the intermediate and final environmental impact. The first category shows homogeneous classes of influences such as climate change, acidification and water ecotoxicity and some others. The second category is formulated on a functional basis and represents the final environmental assessment and the final damage of human activities. It is a fact that "midpoint approaches represents greater reliability, while endpoint approaches represent greater relevancy" (Chan *et al.* 2011, p.90). In conclusion “Normalization makes it possible to translate abstract impact scores for every impact category into relative contribution of the product to a reference situation” (Sweeswijk *et al.* 2008, p.227).

The number of life cycle assessment stages depends on the conditions, requirements and calculation purposes intended by the investigator or auditor. The total number of steps may vary from only three mandatory to seven.

Researchers can find necessary information to fulfill the life cycle assessment in different sources of data: companies’ operating processes, including own measurements; interviews with experts; literature data including publicly available environmental company reports; theoretical models such as design models used in engineering; databases and LCA software; legal maximum emissions values; or qualified estimates based on similar operations (Finnveden & Lindgors 1996).

Life cycle assessment has advantages and disadvantages. On the one hand it studies the whole product system for technical and potential changes and measures not only impact on the environment, but also people’s relation to such an impact. With LCA, “it is possible to compare: various ends of life process for a product; various materials, various systems of products distribution and various manufacturing process” (Millet *et al.* 2007, p.337). On the other hand, it is not a very specific approach; as many economic and social aspects are not included. In addition, such an approach is used for a current product system and there is a risk that “only small improvements can be achieved…” (Andersson *et al.* 1998, p. 290). As well “LCA is not useful in creating a learning dynamic (awareness) within the company, because it does not improve the legitimacy or credibility of environmental consideration” (Millet *et al.* 2007, pp.338).

In spite of many disadvantages, life cycle assessment is widely used all around the world nowadays.

2.1. Life cycle assessment of plastic bags

Different countries have already tried to find the best solution for the grocery bag by using life cycle assessment. For example, the American Chemical Council Plastics Division concluded a comparison of paper and plastic bags using LCA in the USA (Greene 2011). The result demonstrated that plastic bag manufacture demands less energy, water and fossil fuel than paper ones. Moreover, the amount of solid wastes and greenhouse gases are also less.

Another example showed the Australian experience. Consulting Pty Ltd compared high-density plastic grocery bags with several other bags made from paper, compostable plastic, cotton, and polypropylene (ExcelPlas Australia 2004). SimaPro 5.1 software was used for calculations and analysis of the production process, which included extraction of raw materials, production of bags, transportation them to retailers, and disposal at landfills. “The Australian study found that reusable polypropylene bags had the least impact on the environment” (ExcelPlas Australia 2004, p.84).

In the United Kingdom a comparative research of carrying bags was made by the Environmental Agency in 2011. They looked at different variations of carry bags and checked the environmental impact of the whole life cycle. “The following types of carry bag were studied: conventional, lightweight bags made from high-density polyethylene; lightweight grocery bags with a prodegradant additive designed to break down the plastic into smaller pieces; biodegradable bags made from a starch-polyester (biopolymer) blend; paper bags; a “bag for life” made from low-density polyethylene; a heavier more durable bag with stiffened inserts made from non woven polypropylene; and a cotton bag” (Environmental Agency 2011, p.6). The results showed that the environmental impacts of carrier bags are dominated by resource use and production. Transport, secondary packaging and end-life processing generally have a minimal influence on their environmental performance.

To conclude, the results of the above mentioned LCA analyses from different countries it is possible to say that according to short-term environmental impact, plastic grocery bags have the lowest influence. Although if we are looking at long-term harmfulness, biodegradable bags have less impact, such results are not always apparent; therefore measuring the impact on environmental and human health is necessary and important. In addition, resource extraction and manufacturing processes creates the biggest environmental impact among other stages of production.

2.2. Different ways to decrease the impact of plastic bags e.g. by using bags of paper or cloth

Different regulation tools are used for decreasing plastic production and consumption. One radical way is a ban or "plastax". Ireland and Scotland implemented such taxes in 2003 (EuroCommerce 2004) and have achieved quite good results. Consumers shifted their preferences to cloth, paper, biodegradable or compostable plastic bags. Unfortunately, taxes on plastic do not solve the problem of pollution; they just help to shift to more sustainable plastic or other materials.

In the USA, Californian was the first state, where the Plastic Bag Recycling Act of 2006 was established (Food marketing Institute 2010). It forced stores to: "provide bins to collect used plastic bags; print on each bag the message "Please Return to a Participating Store for Recycling"; and maintain records for at least three years documenting recycling activities" (Food marketing Institute 2010). After that campaign many states have changed their plastic bag policy and implemented different tools to decrease usage.

Australia, France and Belgium focused on voluntary initiatives through awareness campaigns in supermarkets (EuroCommerce 2004). Such methods and mechanisms are used for reducing the production and consumption of plastic bags. This instrument can be successful only in a society with high environmental awareness. Those actions helped to change the packaging behavior of the customers.

The main problem with plastic bag production is the formation of long-degradable wastes. Disposal in landfills or littering in public places is the final destinations of such products (Ayalon *et al.* 2009). Plastic wastes are a huge problem. In developing countries, the consequences are much more severe and the level of pollution is higher, because of lack of education and finances, and political and economic instability.

2.3. Waste management and plastic bags

In Ukraine environmental problems are attracting public attention more and more public attention. Among these problems, waste is on the top of the discussion agenda now, because of the critical and dangerous situation. Unfortunately, during the last 10 years, waste creation per capita has increased by 75% and today it is 300-400 kg per year (Bondar and Poltorachenko 2011). In Ukraine there are two ways of dealing with waste: disposal to landfills or incineration. Waste separation is performed very rarely in Ukraine and present only in a few cities. Indeed, 50 million m^3 of municipal solid waste was created in 2010, which is about 11 million tons of waste, disposed of at 4500 landfills and dumps with general area of more than 8000 ha in 2010 (Bondar and Poltorachenko 2011). The situation is critical and requires decisive action today, because landfills are overfilled and technically outdated. In addition, illegal disposing of waste in natural landscape formations is wide spread. The reason behind it is very simple: money. In order to dispose of waste in official landfills, companies have to pay fees, while disposing it illegally is free, even though it is forbidden by law. Life is done to prevent this kind of behaviour. 35000 illegal dumps were discovered in 2010, and almost all of them were removed same year (Bondar and Poltorachenko 2011). In addition to the situation described, almost all kinds of plastic produced in Ukraine, are not compostable or biodegradable, and that is why they just end up at the landfill for the next hundreds of years.

In Ukraine, over-packaging is a big problem, which is not seen as an environmental challenge or harmful by locals. Plastic is the material which is mostly used for packaging. As single-use plastic bags are usually free at supermarket checkpoints, consumers try to put each item of commodities in a separate bag. With such a situation, the supply of lightweight bags is dramatically increasing, but people do not understand the consequences. Only flying bags on the street and hanging on the trees and bushes can attract their attention. As was mentioned above, low environmental awareness and financial instability in the country is the background for Ukrainians not thinking about future consequences in a long term perspective.

Plastic is not seen as a very dangerous material; therefore campaigns against it are rare. Nowadays a better way of dealing with plastics is being presented in Ukraine. For example, in Novomorsky, Dnipropetrovs'k region, polyethylene bags are forbidden (CUHECU 2011). This is nothing if you compare the scale of one city to the huge territory of Ukraine - 603,700 square kilometers (Odessa Realty Group 2012) and 45 603 210 millions of inhabitants (State Statistics Service of Ukraine 2011). Another possible way of dealing with the overproduction of plastic bags is the advertisement of eco-bag campaigns at particular shops and supermarkets. For an example, the shoes store "INTERTOP" has a promotion for using eco-bags (textile) with the label "I'm for clean life". All money from sold bags is used for environmental events, such as planting trees or sponsoring the organization of the "Earth Day" (Shop "INTERTOP" 2011). A good sign is the popularization of an environmental life style among young Ukrainians and their wish to be more recourse efficient consumers and sustainable thinkers. Unfortunately these rare examples do not have mass media, governmental or educational institution support. To conclude, everything mentioned above with regard to research in measuring the environmental impact of plastic bag production is new and necessary for the Ukrainian consumer market (producers/suppliers/consumers) and environment. Unfortunately, there is no single national plan regarding plastic bag production and recycling, but there are many local improvements in this field.

2.4. Main types of plastic bags production

Plastic bag production is a very complicated process with many stages. Synthetic and natural materials are used in the manufacturing process. The main component for synthetic bags is ethylene, a by-product of oil, coal or gas refining. The polymerization reaction transforms ethylene into polyethylene in a pellet form, which is used by plastic producing factories.

Conventional (traditional) plastic bags can be made from high- (HDPE) or low- (LDPE) density polyethylene. Bags differ in thickness and durability, according to different consumers' requirements. HDPE has stronger textile strengths and is not as soft as LDPE. Unfortunately, these kinds of plastic bags are mostly not biodegradable and not consumed by microorganisms in the soil.

Degradable plastic bags have the ability to break down by bacterial (biodegradable), thermal (oxidative) or ultraviolet (photodegradable) action (James 2004). *Biodegradable plastic bags* are an option for which mostly natural materials are needed, and also with the right technology can be broken down by bacterial action with no by-products or toxic residuals after degradation. For biobased polymer next materials can be used: starch from corn, tapioca, wheat, potato, rice, etc; oils form seed, linseed, palm, soy beans, etc; or fermentation products, like polylactic acid, polyhydroxyalkanoate, and polyhydroxybutyrate (CIWMB 2007). Usually the degradation process requires specific conditions, which can be provided by specific waste management companies. *Compostable bags* degrade under special composting conditions, which mean that microorganisms break them down, followed by a mineralization process (James and Grant 2004). There are three more kinds of degradable bags, such as oxo-biodegradable, photodegradable and water-soluble bags, which require natural daylight, heat and or mechanical stress; ultraviolet; or water with a specific temperature (James and Grant 2004) in order to break down.

2.5. Plastic bag production at the limited liability company "Polymer"

The manufacturing process of plastic bags can vary, but in general it includes several main steps. The production process used by the Ukrainian LLP "Polymer" is described as a typical example. First step is the conversion of plastic film. Different types of polymer granules (pellets) are melted and extruded as continous tube in the convertors. The strength, thickness and color are dependent on the customers' wishes and requirements. Any color can be modified by mixing different dyes, which are in granulated form as well. The engineers calculate the proportion of materials for the first charging to get the required result. The sacks with granulate dyes, which are used by the enterprise, are presented below on the Figures 2-3.

Figure 2. Bags with different dyes.

Figure 3. Bag with black dye.

The convertors produce a film tube, which is inflated with air. That helps to form a bubble for cooling down and solidification of the film. The point at which the required thickness of the film is reached is named the frost line. After that, "the tube is guided by collapsing boards and gradually flattened and gusseted as it approaches the pinch rolls. When the film passes between them, the top of the bubble is effectively sealed. The flat film is fed to the winding equipment via a pre-treatment and slitting unit. Slitting and trimming is a continuous operation. The flat film is then wound onto rolls" (FRIDGE 2012, p.36).The process is presented in Figures 4-5 below. The left picture shows production polyethylene film for garbage bags and the right one is a film for green houses.

Figure 4. Film manufacturing.

Figure 5. Film manufacturing.

The second step is vest-bag manufacturing which means that the gusseted film is unwound first and then passed through different rollers. Defective film is crushed, extruded rod is formed with the desired diameter (3-4 mm), and crushed to granules (LLC "Polymer" 2011), which are reused in production. Sometimes the film has to be passed under ultra violet lights for better printing quality. A lot of ozone is emitted to the air and it is easy to smell it at the gild.

Next step is the printing of patterns. Customers can choose any design or emblem. Usually carry bags have a pattern with the logo of the company, for which different inks and dyes are used to print the design/brand. After decorating "the printed film is passed through rollers, sealed and cut at predetermined lengths" (LLC "Polymer" 2011). When bags are ready, they are bundled and baled for distribution.

The last stage of current research is delivery of vest-bags to the warehouse, however in reality; the next step is distribution and consumption. Plastic bags are used to hold purchased commodities. The last step is reusing several times and throwing them into the garbage bin. This is not the end of bags life cycle, since their degradation period is very long, yet people forget about that at the moment they throw the bags away.

The LLC "Polymer" produces different types of plastic bags, but in my research I focused on traditional and biodegradable vest-shaped bags only. Such formed bags are very popular among customers, because of quality characteristics: low cost, large capacity, high strength, ease of use, etc. Sketches of vest-shaped bags produced by the enterprise are shown below on the Figure 6.

For life cycle assessment it is very important to choose a functional unit (FU). According to the definition: "it is a relevant and well defined, strict measure of the function, that the system delivers (user function) and it is the basis for the analysis" (Finnveden & Lindgors 1996, p.45). The functional unit of this research is 1000 items of plastic bags, but for SimaPro7.3.2 software, this amount was transformed in kilograms. One thousand traditional bags weigh 23.3 kilograms. At the same time, the weight of 1000 biodegradable bags is 22.6 kilograms. In Vinnitsa region, traditional vest-bags are widely used by customers, but biodegradable ones are only made for special clients, like McDonalds.

Figure 6. The Vest-plastic bags produced by LLC "Polymer".

Identifying the research system boundaries is the next step, which "includes defining the product system(s) to be studied (process tree), limitations in the life-cycle, geographic boundaries, and boundary between technosphere and biosphere in the relation to the goal of the study" (Finnveden & Lindgors 1996, p.46). The graphical view of the system boundaries is presented below on the Figure 7, which shows that all stages of productive process which are in the green area are included in calculations. In our case, it is transportation of the materials to the company and manufacturing process till sending to warehouse. Thin black arrows show the transition from one productive step to another. The inputs and outputs of materials to the research system are shown by thick white arrows. At the same time emissions to the atmosphere during transportation and manufacturing are presented by thick blue arrows.

The first stage of the productive process is buying materials and recourses from suppliers. Polyethylene granules, dyes and solvent are bought at the open-end company "Kazansyntez", which is located in Kazan city, Russia. Polylactacide granules are provided from "TOSAF" company, Kyiv, Ukraine. All transportation of materials from their producers to the enterprise "Polymer" is made by lorry type "MAN" (a 12100 tone vehicle). It produces with emissions of carbon dioxide and monoxide, methane, nitrogen oxides, sulfur oxide and the other compounds to the atmosphere.

The next steps are "Film production" and "Vest-bags production". All the remains of polyethylene film are recycled and recycled. There are special machines which transform scraps into pellets which are used again for film manufacturing.

The last two stages which are included in my research are printing pattern and transporting to the warehouse. Plastic bag's life cycle is not ended at this stage, but according to data limitations it is the last point of my research. Moreover, the LLC "Polymer" is more interesting in their impact during the production process, because it is a stage which they can improve.

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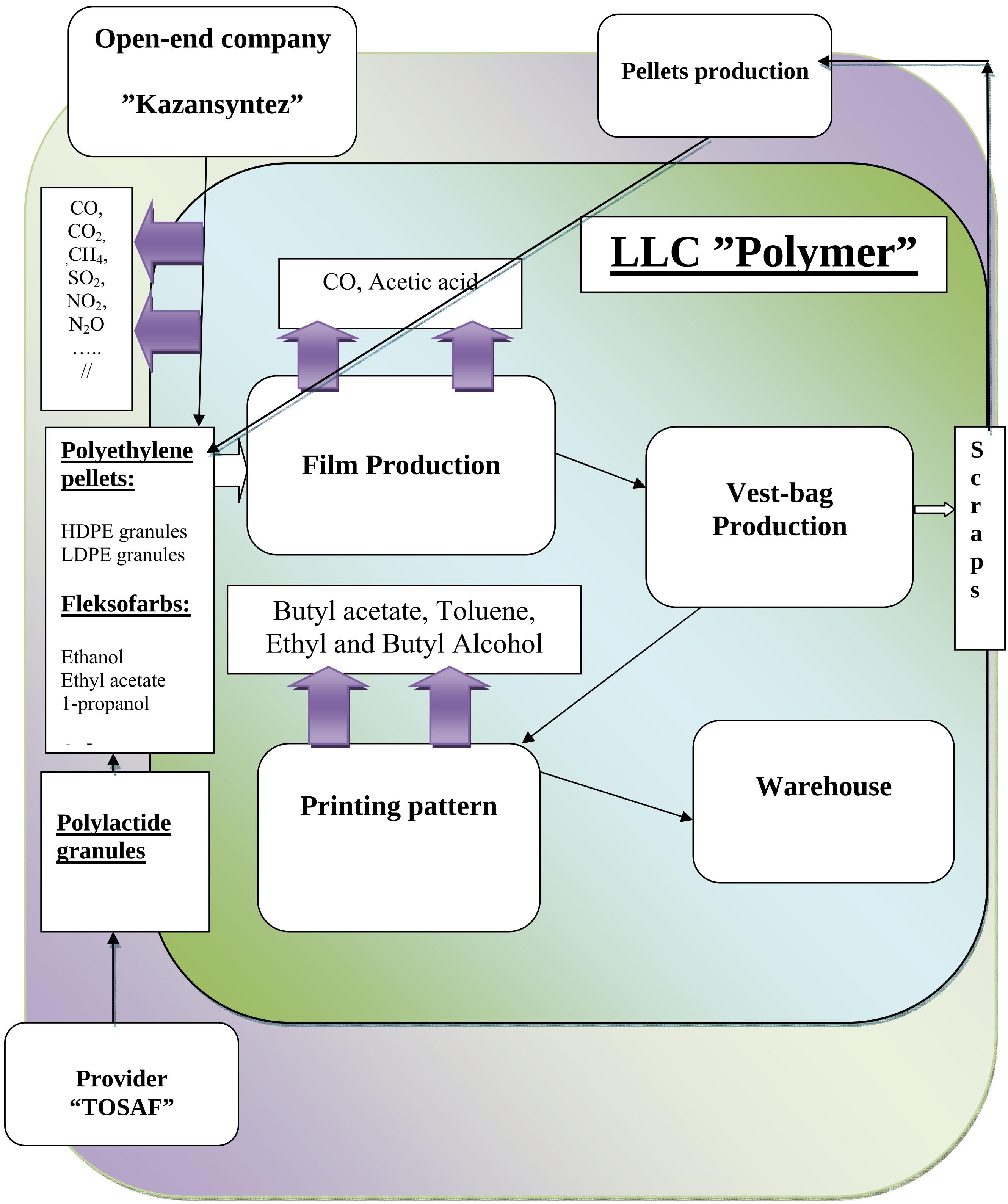

Figure 7. System boundaries of the plastic bags manufacturing.

3. Results

Inventory analysis is the second phase of life cycle assessment. It is used for identifying and qualifying the inputs and outputs of the productive process. As was mentioned above, this research is focused on the manufacturing of two types of plastic vest-bags: traditional and biodegradable. The results of collecting data are analysed, transformed according to the estimated functional unit and system boundaries, grouped and visualised below in the Table 1. Information is provided separately for traditional and biodegradable carrying vest-bags, "in the way of easy understanding and preparation of a basis for the nest step of LCA – impact assessment" (Zbicinski 2006, p.97).

The first part of the inventory table shows the variety and amount of recourses which are needed for vest-bag production and printing the pattern upon them. Inputs for product cycle include resources from nature and materials from technosphere. So, for the manufacturing of 1000 traditional bags 12.7 kilograms of low density polyethylene granules and 10.7 kilograms of high density polyethylene granules are needed. The inter mixture of granules for 1000 biodegradable bags is different; it requires 4.6 kilograms of low density polyethylene granules, 6.3 kilograms of high density polyethylene granules and 11.7 kilogram of polylactide granules. The numerical superiority of the previously mentioned component causes a biodegradable characteristic of these bags.

Moreover, the usage of fuel (diesel) by lorries for the transportation from suppliers is also taken into consideration. All materials are transported by lorry "MAN" to the enterprise "Polymer" from different cities in Ukraine and Russia. Supplier of LDPE and HDPE granules is the open-end company "Kazansyntez", which is located in Kazan city, Russia, a distance is 1,901 kilometers. The polyactide granulate is bought from provider "TOSAF" in Kyiv, and also transported with the same vehicle, but the distance is only 245 kilometers. That is why the diesel consumption for transportation of 1000 traditional and biodegradable bags is different in the Table 1.

The inputs include special dyes and solvent (toluene), which are used for printing the pattern. Dyes are based on ethanol, ethyl acetate and 1-propanol.

The outputs of the product life cycle are emissions to the air, water, soil, and disposal of wastes. The research productive cycle is a significant, because harmful substances are only emitted to the atmosphere. They include the following pollutants: abietic acid, butyl acetate, toluene, ethanol, butanol 2 methyl-1, carbon monoxide and dioxide, non-methane volatile organic compounds, methane, nitrogen dioxide and monoxide, soot, benz(o)pyrene and sulfur dioxide. Their amount is presented in kilograms related to the production of 1000 items of two kinds of carrying bags. Moreover, there is no water pollution or harmful wastes and all by-products are recycled and used in the production process again.

Table 1. Inventory data of traditional and biodegradable plastic bags production.

Resources / Emissions	Units	Traditional Bags	Biodegradable Bags
Resources			
Polyethylene, LDPE, granulate	kg	12.6	4.6
Polyethylene, HDPE, granulate	kg	10.7	6.3
Polylactide, granulate	kg	0	11.7
Diesel	kg	0.0681	0.076
Dyes:			
Ethanol from ethylene	kg	2.1432	2.2816
Ethyl acetate	kg	0.453	0.485
1-propanol	kg	1.8753	1.996
Toluene E		0.643	0.643
Air Emissions			
Abietic acid	kg	0.00812	0.00791
Butyl acetate	kg	9.7005	9.7855
Toluene	kg	3.9917	4.1275
Ethanol	kg	1.9401	1.9575
Butanol, 2-methyl-1-	kg	3.9917	4.0275
Carbon monoxide	kg	0.0080683	0.000849
NMVOC (non-methane volatile organic compounds)	kg	0.0011	0.0011
Methane	kg	3.26197E-5	3.53243E-5
Nitrogen dioxide	kg	0.0041	0.0044
Soot	kg	0.0005	0.0006
Nitrogen monoxide	kg	1.56574E-5	1.69557E-5
Carbon dioxide	kg	0.409441992	0.4434
Benz(o)pyrene	kg	3.91436E-6	4.23891E-6
Sulfur dioxide	kg	0.0005	0.0006

After the “Inventory analysis” I shifted to the “Impact assessment” step. Results of the characterisation, normalization and single score stages are viewed below for traditional and biodegradable bags separately for the figures 8-17. The first bar chart shows fifteen impact categories of the traditional vest-bags production, which can be divided into two groups according to their influence on the environment or human health. The first group includes ionizing radiation, ozone layer depletion, aquatic ecotoxicity, terrestrial ecotoxicity, terrestrial acid/nutri, land occupation, aquatic acidification, aquatic eutrophication, global warming, non-renewable energy and mineral extraction. Another consists of carcinogens, respiratory inorganics, non-carcinogens, and respiratory organics categories. They are red columns on the horizontal OX axis. The scale of vertical axis OY is 100 %, which gives evidence to the harmfulness of the categories.

Impact category	Unit	Total
Carcinogens	kg C2H3Cl eq	5,29
Non-carcinogens	kg C2H3Cl eq	0,247
Respiratory inorganics	kg PM2.5 eq	0,0295
Ionizing radiation	Bq C-14 eq	246
Ozone layer depletion	kg CFC-11 eq	1,33E-6
Respiratory organics	kg C2H4 eq	7,38
Aquatic ecotoxicity	kg TEG water	1,18E3
Terrestrial ecotoxicity	kg TEG soil	153
Terrestrial acid/nutri	kg SO2 eq	0,714
Land occupation	m2org.arable	0,0342
Aquatic acidification	kg SO2 eq	0,21
Aquatic eutrophication	kg PO4 P-lim	0,00527
Global warming	kg CO2 eq	53,8
Non-renewable energy	MJ primary	2,22E3
Mineral extraction	MJ surplus	0,146

Figure 8. Results of the characterization stage of traditional vest-bag production.

This table shows the same results as the bar chart above, but in a different format. The first column is the name of the impact category, the second – is the units of emissions, the third and fourth - are emissions during production of traditional vest-bags.

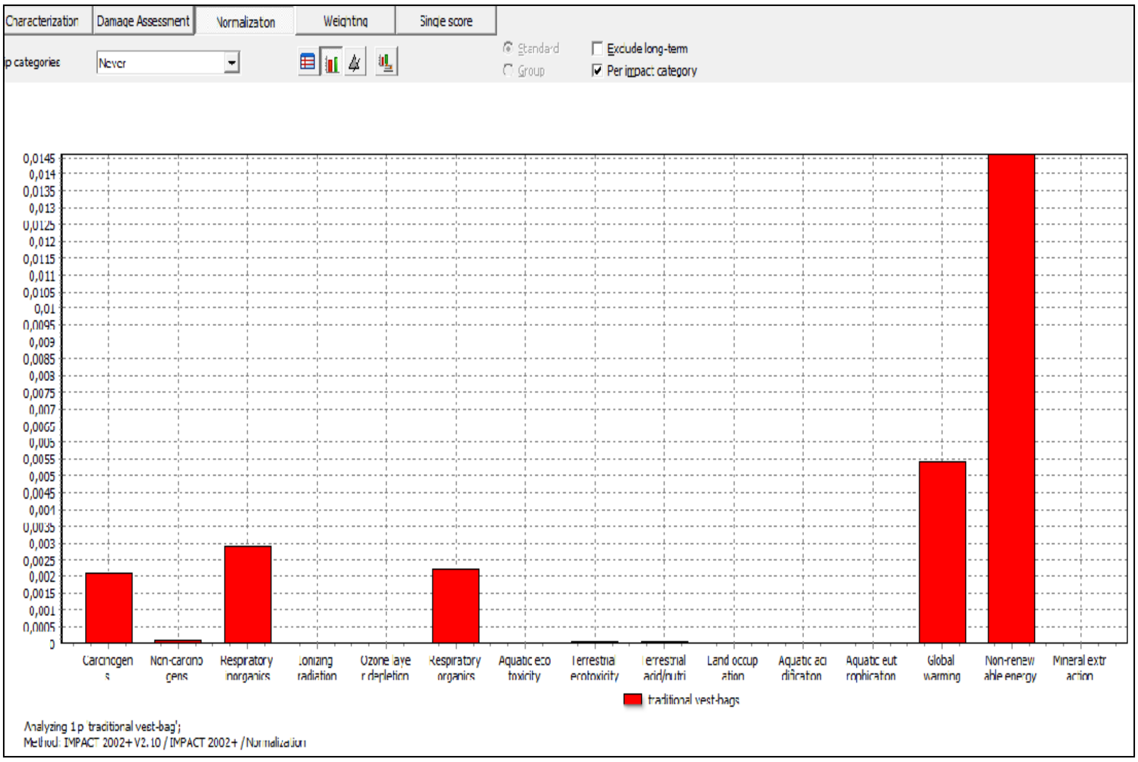

Figure 9. Visualization of the normalization stage of traditional vest-bag production.

Figure 9 presents the results of the normalization stage of the conventional bag life cycle. The OX axis shows the same fifteen categories, but the scale of OY axis has changed. SimaPro 7.3.2 software has made several calculations and transformed different units of emissions to one scale – milli Ecopoints (mPt). Hence, the level of every impact category is presented on the bar chart. The biggest influence among all categories is caused by the using of “non-renewable energy” resources. The next ones are “global warning”, “respiratory non-organics”, “respiratory organics” and “carcinogens”. All the other impact categories have much lower influence on environment and human health.

Figure 10 shows the final result of traditional vest-bag life cycle assessment. “Single score” step presents the same results normalization with the scale (mPt) as, but in a differently visualized way. It is a single column with different color and thickness layers, which represent different categories and levels of impact.

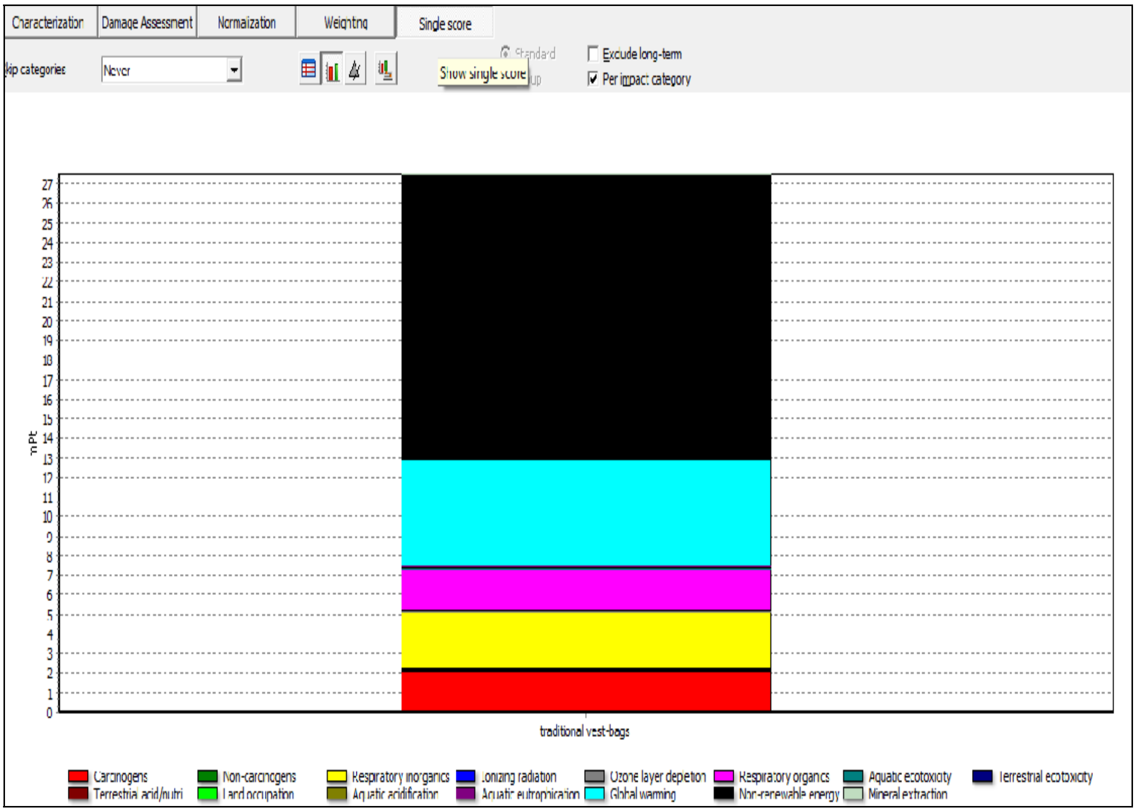

Figure 10. Visualization of single score calculations for traditional vest-bag production.

The other way to present results of “Single score” step is a table, which is shown on the figure 11. It shows the particular contribution of all 15 categories in the same unit (mPt).

Sel	Impact category	Unit	Total
	Total	Pt	0,0275
	Carcinogens	Pt	0,00209
	Non-carcinogens	Pt	9,77E-5
	Respiratory inorganics	Pt	0,00291
	Ionizing radiation	Pt	7,29E-6
	Ozone layer depletion	Pt	1,96E-7
	Respiratory organics	Pt	0,00222
	Aquatic ecotoxicity	Pt	4,32E-6
	Terrestrial ecotoxicity	Pt	8,83E-5
	Terrestrial acid/nutri	Pt	5,42E-5
	Land occupation	Pt	2,72E-6
	Aquatic acidification	Pt	-
	Aquatic eutrophication	Pt	-
	Global warming	Pt	0,00543
	Non-renewable energy	Pt	0,0146
	Mineral extraction	Pt	9,62E-7

Figure 11. Results of the single score calculations of traditional vest-bag production.

The same measurements were made for the biodegradable vest-bag, which are produced by LLC “Polymer”. The outcome is different and shown on the Figures 12-16.

The categorization stage identified same 15 categories, which are shown on the Figure 12.

Skip categories: Never

Sel	Impact category	Unit	Total
	Carcinogens	kg C2H3Cl eq	3,14
	Non-carcinogens	kg C2H3Cl eq	0,121
	Respiratory inorganics	kg PM2.5 eq	0,0365
	Ionizing radiation	Bq C-14 eq	1,44E3
	Ozone layer depletion	kg CFC-11 eq	4,95E-6
	Respiratory organics	kg C2H4 eq	7,46
	Aquatic ecotoxicity	kg TEG water	4,66E3
	Terrestrial ecotoxicity	kg TEG soil	219
	Terrestrial acid/nutri	kg SO2 eq	1,06
	Land occupation	m2org.arable	13,7
	Aquatic acidification	kg SO2 eq	0,252
	Aquatic eutrophication	kg PO4 P-lim	0,029
	Global warming	kg CO2 eq	64,5
	Non-renewable energy	MJ primary	1,86E3
	Mineral extraction	MJ surplus	0,514
	Mineral extraction	Pt	9,62E-7

Figure 12. Results of the characterization stage of biodegradable vest- bag production.

Figure 13 presents a list of all fifteen categories with their amount of emissions with different units. That is why it is impossible to compare the level of impact of each category on this stage. Therefore normalization is a necessary step.

During the normalization step, the impacts of categories were differently distributed according to their influence. Evidently, there is a difference in the normalization results of traditional and biodegradable bags. Firstly, the impacts of “land occupation”, “global warming”, “land occupation” and “terrestrial ecotoxity” categories have slightly increased. Secondly, the opposite tendencies are shown for “carcinogens” and “respiratory inorganic”, which have decreased. Figure 1 and Figure 14 illustrate that.

The software transformed the amount of emissions to the same scale, which gave evidence to the harmfulness of the categories.

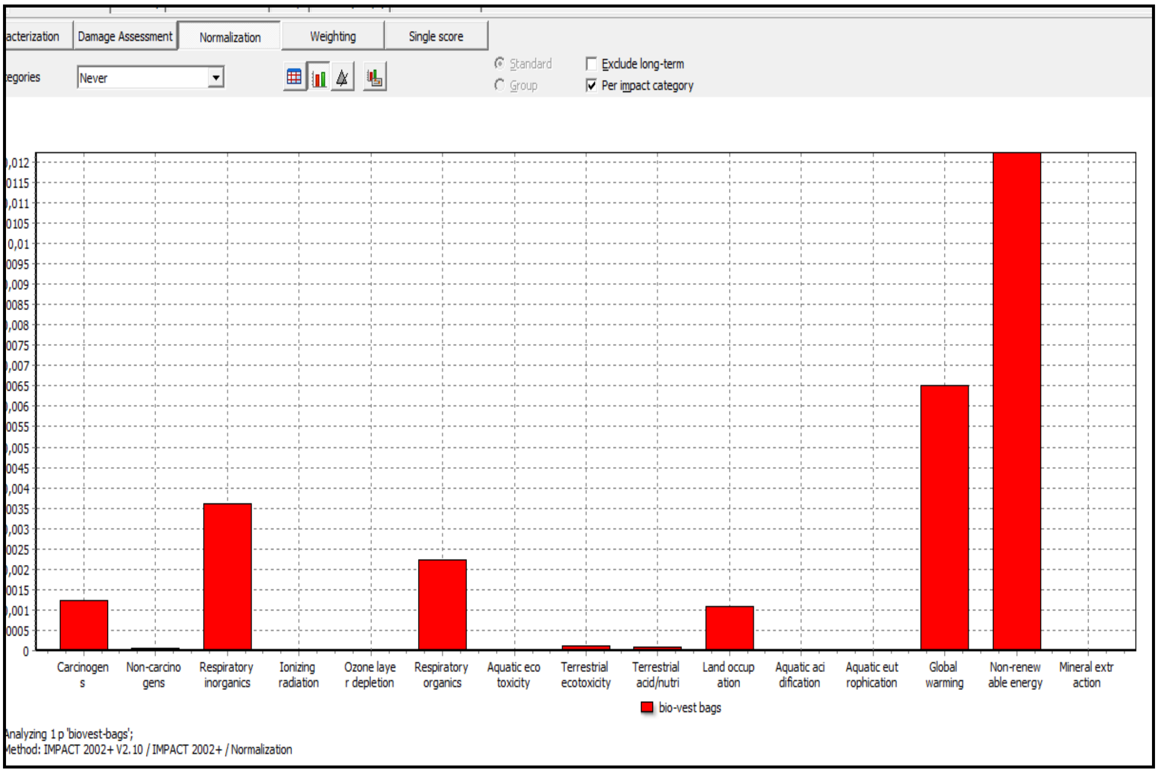

Figure 13. Visualization of normalization stage of biodegradable vest-bag production.

Sel	Impact category	Unit	Total
	Total	Pt	0,0272
☑	Carcinogens	Pt	0,00124
☑	Non-carcinogens	Pt	4,76E-5
☑	Respiratory inorganics	Pt	0,0036
☑	Ionizing radiation	Pt	4,26E-5
☑	Ozone layer depletion	Pt	7,33E-7
☑	Respiratory organics	Pt	0,00224
☑	Aquatic ecotoxicity	Pt	1,71E-5
☑	Terrestrial ecotoxicity	Pt	0,000126
☑	Terrestrial acid/nutri	Pt	8,07E-5
☑	Land occupation	Pt	0,00109
☑	Aquatic acidification	Pt	-
☑	Aquatic eutrophication	Pt	-
☑	Global warming	Pt	0,00651
☑	Non-renewable energy	Pt	0,0122
☑	Mineral extraction	Pt	3,38E-6

Figure 14. Results of normalization stage of biodegradable vest-bag production.

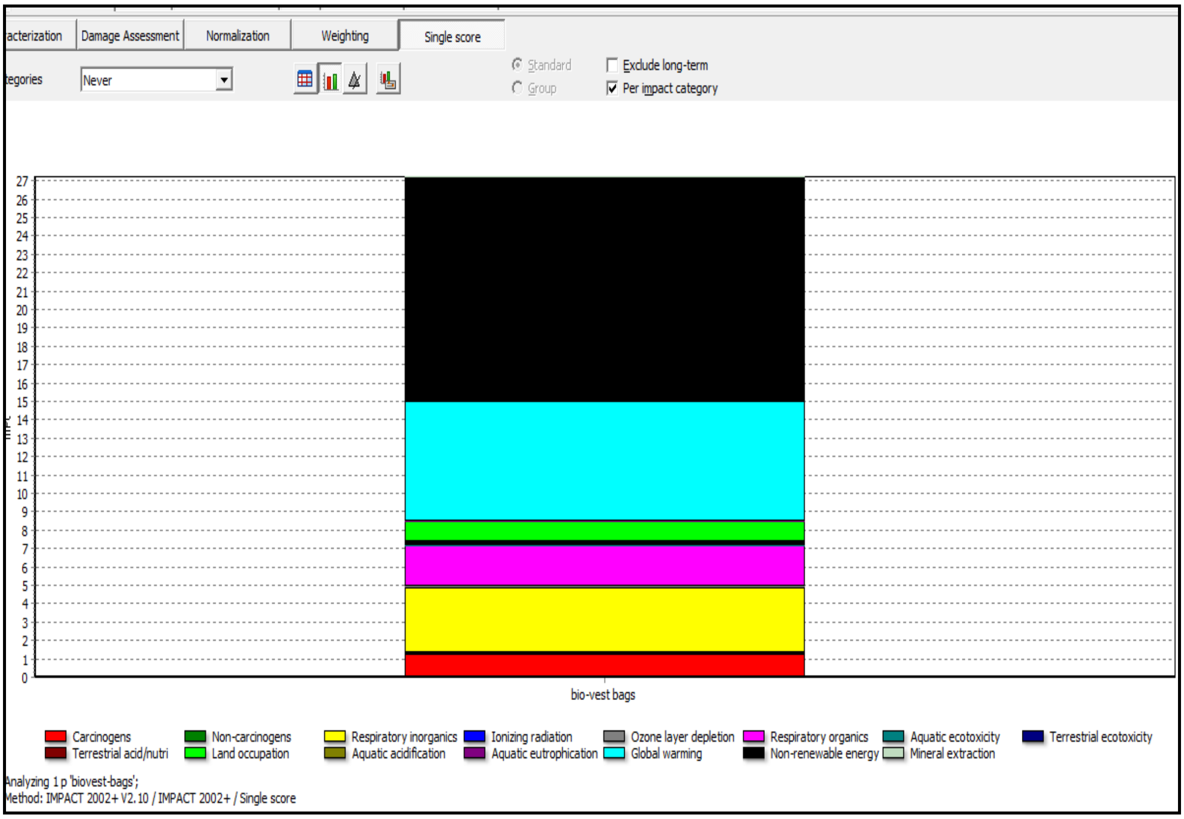

Figure 15. Visualization of single score calculations of biodegradable vest-bag production.

Results of “single score” are visualized in Figure 15. It shows that consumption of “non-renewable energy” resources is the biggest contribution to the general impact of biodegradable bags production. Next categories are “global warming” (blue layer), “respiratory non-organics” (pink layer), “respiratory organics” (yellow layer), “carcinogens” (red layer) and “land occupation” (green layer). All other five are less harmful for the environment and human health.

IMPACT 2002+ method was also used to compare 1000 of traditional and biodegradable vest-bags at the same time. It is applied in identify the more environmental friendly type. The results of characterisation, normalisation and single score stages are shown in the bar charts and tables below. Figure 16 presents the results of the categorization step, which incorporates fifteen categories. Green columns are traditional bags and red are biodegradable bags. The scale of vertical OY axis is 100 percent. It is shown, that impact of each category is different for two types of bags, depending on the height of the columns.

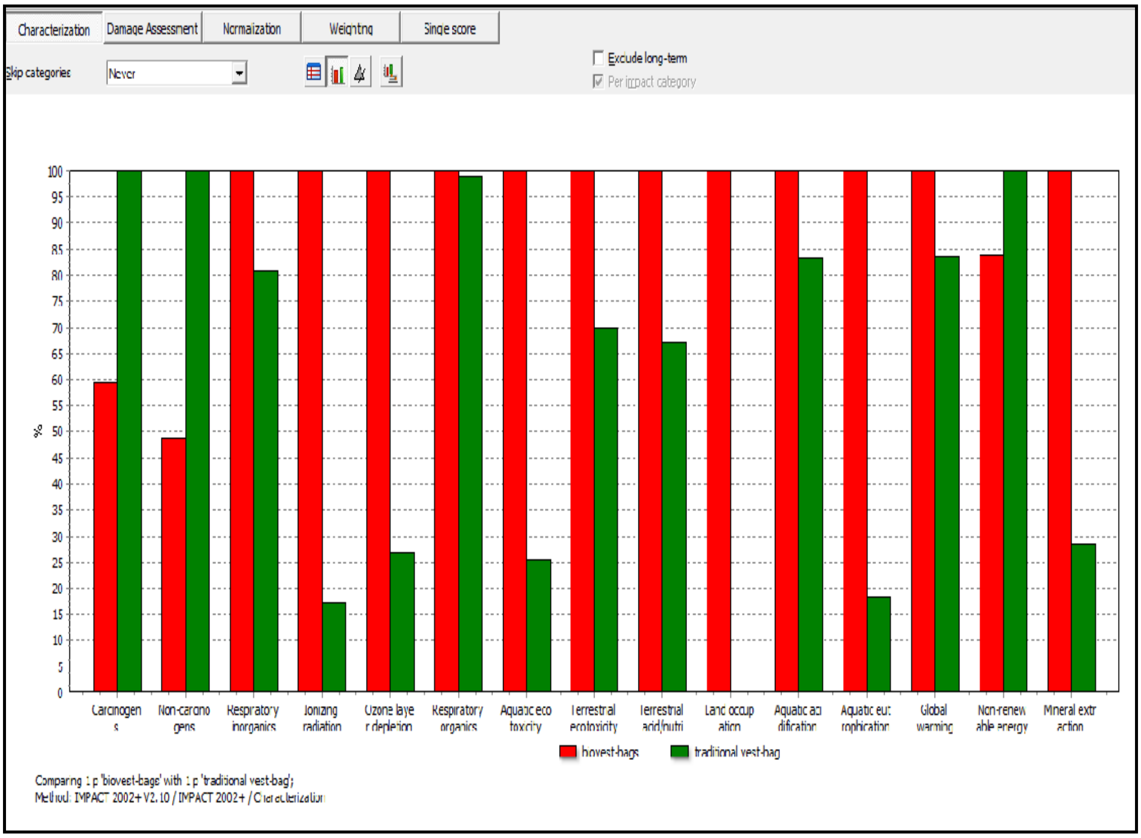

Figure 16. Visualization of characterization stage of biodegradable and traditional vest-bag production.

Sel	Impact category	Unit	biovest-bags	traditional vest-bag
☑	Carcinogens	kg C2H3Cl eq	3,14	5,29
☑	Non-carcinogens	kg C2H3Cl eq	0,121	0,247
☑	Respiratory inorganics	kg PM2.5 eq	0,0365	0,0295
☑	Ionizing radiation	Bq C-14 eq	1,44E3	246
☑	Ozone layer depletion	kg CFC-11 eq	4,95E-6	1,33E-6
☑	Respiratory organics	kg C2H4 eq	7,46	7,38
☑	Aquatic ecotoxicity	kg TEG water	4,66E3	1,18E3
☑	Terrestrial ecotoxicity	kg TEG soil	219	153
☑	Terrestrial acid/nutri	kg SO2 eq	1,06	0,714
☑	Land occupation	m2org.arable	13,7	0,0342
☑	Aquatic acidification	kg SO2 eq	0,252	0,21
☑	Aquatic eutrophication	kg PO4 P-lim	0,029	0,00527
☑	Global warming	kg CO2 eq	64,5	53,8
☑	Non-renewable energy	MJ primary	1,86E3	2,22E3
☑	Mineral extraction	MJ surplus	0,514	0,146

Figure 17. Results of characterization stage of biodegradable and traditional vest-bag production.

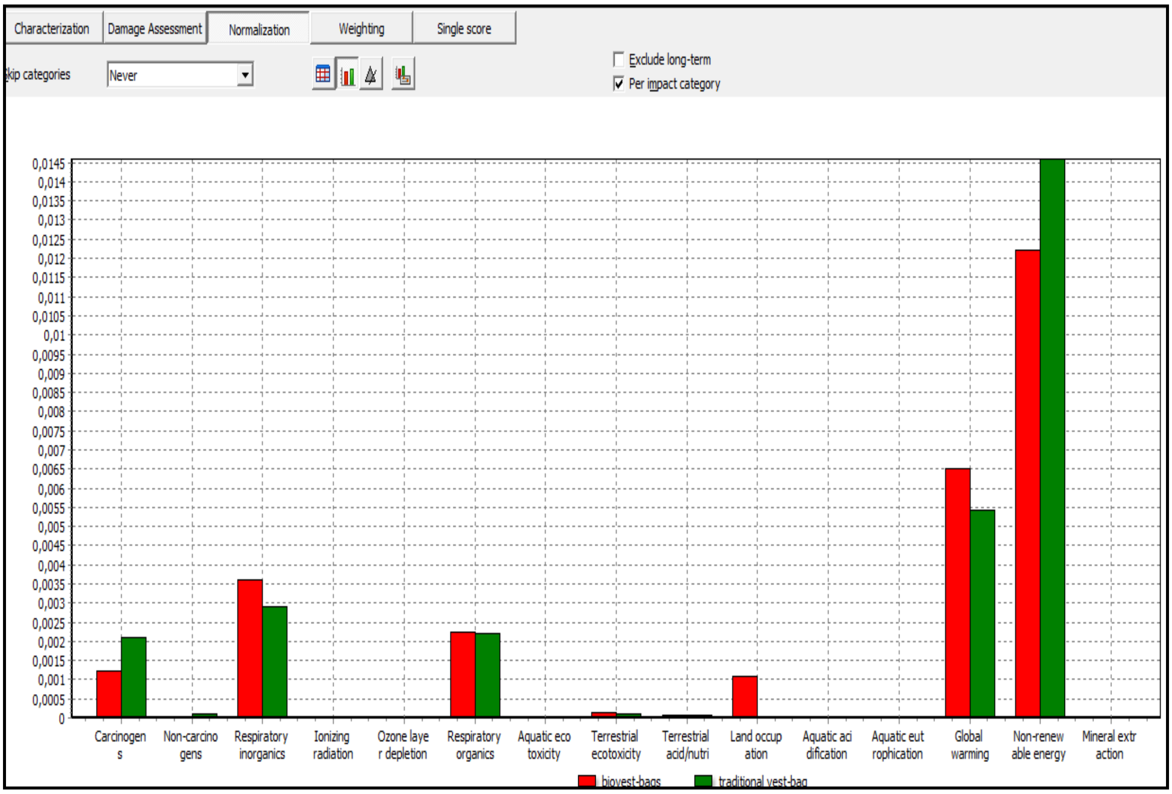

Figure 18. Visualization of normalization stage of traditional and biodegradable vest-bag production.

The normalization stage shows that the production of conventional bags involves higher numbers in the “carcinogens” and “non-renewable energy” categories, but the situation is opposite for the “respiratory inorganic” and “global warming” impact categories. “Land use” plays an important role only for biodegradable bags only. The scale of vertical OY axis is milli ecopoints (mPt), the units are the same for all categories.

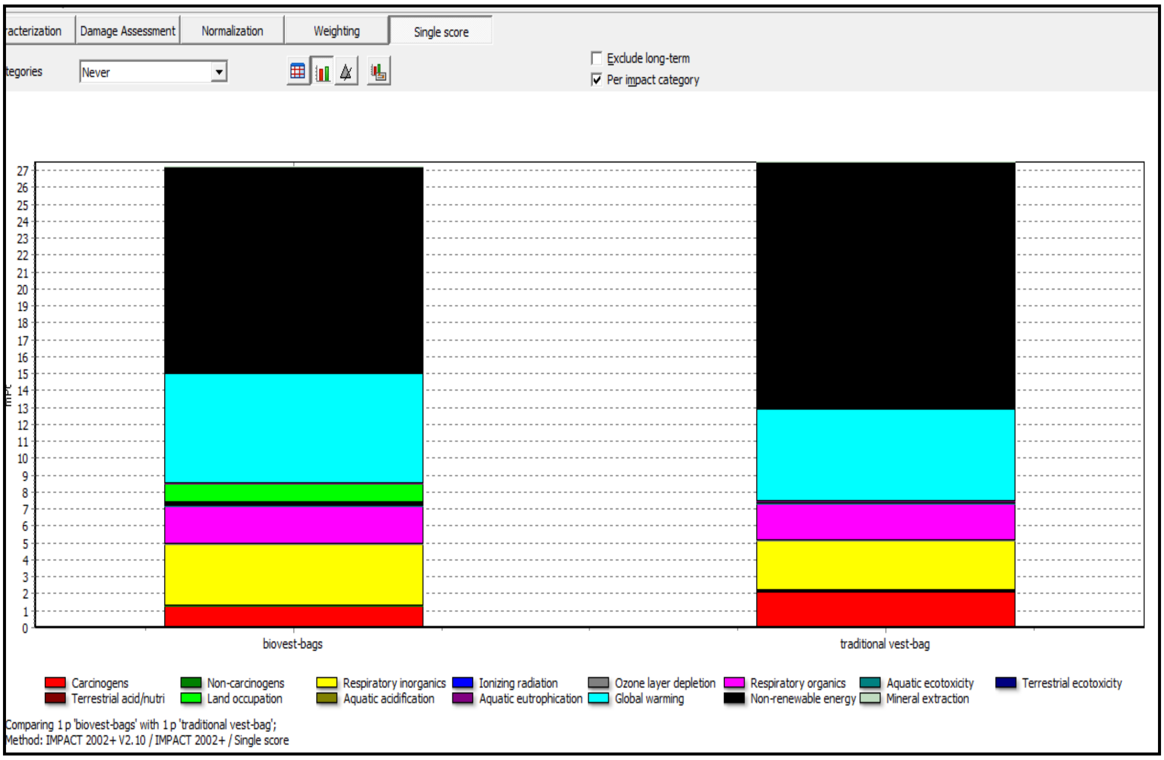

Figure 19. Visualization of the single score calculation for traditional and biodegradable vest-bags with pattern production.

The last "single score" bar chart shows the results of life cycle assessment of two different types of carrying vest-bags. The first column represents the outcome of biodegradable bags with 26.5 milli ecopints (mPt) in total. The second one visualized the results of traditional bags with 27 milli ecopoints Manufacturing of traditional bags is more harmful according to the IMPACT 2002+ method.

4. Recommendations

The culmination of this research was a list of recommendations of the possible improvement of the environmental aspects during the production life cycle in the limited liability company "Polymer". They can help to get ISO 1400X certification in the future. It is a fact that this certificate will increase competitive ability of the enterprise and open borders for sales, which is important in the conditions of current economical slowdown. The list of recommendations is as follows:

- developing and implementing an environmental management system at the enterprise;
- adding sustainable issues to the company's strategy and goals;
- focusing on biodegradable bags production through increased supply;
- improving the manufacturing process through time, which means implementing new environmental friendly technologies for all kinds of productions;
- decreasing transportation distance of materials, through finding suppliers, which are located closer;
- organizing workshops and seminars about the environmental impact of plastic bag production and increase awareness about changing strategy of development;

- preparing the enterprise's documents for an environmental auditing and life cycle assessment by the certified organization.

5. Discussion

The study clearly shows that production of 1000 traditional plastic vest-bags causes a more pronounced negative impact on environmental and human health than the same number of biodegradable ones. The results of the "single score" stage of IMPACT 2002+ method which are presented on the Figure 21, confirm this. The difference between two types of vest carrying bags is not very significant, only 0.5 milli ecopoints, but it still exist. These units were created for simplifying measurements and unifying of final results. The main impact categories are the use of "non-renewable energy", and "global warming"; followed by three from the human health group: "respiratory inorganics", "respiratory organics" and "carcinogens". "Land occupation" is an important category for biodegradable bags only. All other categories have less influence.

Australia, Sweden, the USA, the UK and other countries have already gained experience in the of life cycle assessment for choosing the best option for grocery carrying bags. It is happen because of higher environmental awareness of their society and sense of responsibility to the next generations there. In contrast, such researches in developing countries and countries with transition economies are quite rare nowadays, because of a different way of functioning and dealing with problems. Unfortunately, they are working in a way of hotspots, which means dealing with current problems and visual effects, but not with the underlining cases. Long term management and thinking about long term future consequences is not common in Ukraine. Even if it is a fact that traditional plastic bag makes a big environmental impact on environment, its production and consumption is still dramatically increasing every year. The research presented in this thesis is unique for Ukraine, especially because of using SimaPro 7.3.2 software for assessing of the harmfulness of plastic bag production.

The world experience of comparison of the traditional and others types of carrying bags, such as paper, biodegradable, calico or other, shows that production of conventional bags causes less environmental damage in short term perspective. It means when only resources and materials for production are taken into consideration, but not the fact that degradation period around 500 years on the landfill (Lapidos 2007). When for the biodegradable it much less for a total disappearance, but it required special conditions. The outcome of my studies showed the opposite result. Biodegradable bags are more sustainable than traditional. The possible reasons for those differences in functional units, scales of system boundaries, list of materials used for production etc.

Unfortunately, there are some weaknesses and uncertainties in my study. It happened because of several reasons. Firstly, it is a fact that system boundaries are usually framed by the researcher according to the aims and requirements and don't include all stages of manufacturing process. In the master thesis paper it is difficult to include all the aspects of the product system, because of the lack of time, data and funding. That's why current research is limited and excluded some stages of life, especially after bags are produced. Secondly, assessment of life cycle of only one product is not enough for implementing recommendation for developing a "greening" strategy at the LLC "Polymer".

The strength of this research is the validity of data and information which was taken from the enterprise environmental reports, production descriptions and personal experience of quality manager and main engineer. There were no assumptions and estimations of initial information. Moreover, I used SimaPro 7.3.2 software, which is a well-known and widely used all around the world by certified organizations for life cycle assessment. That is why the results of it are reliable for the scientific and decision-making society.

Based on such results a list of recommendation for improvement of technical and management systems at the enterprise was created and sent to the LLC "Polymer". It is a first initiative for certifying the enterprise according to ISO 1400x standard, which is important for further development and competing for customers on the Ukrainian and European market. That is very important in the current situation of global economic slowdown and increasing pressure of environmental problems.

6. Conclusion

Many artificial materials are found on the Earth nowadays. The influence of many of them on environmental and humans health is still unknown. As was already mentioned, plastics belong to this category. People mostly focus on the good characteristics, such as low cost, large capacity and variety, high strength, ease of use, etc., and forget about long-term harmful consequences and impacts. Lightweight plastic bags are used by almost by everyone all around the world. When we throw them away, we forget about their existence. Unfortunately, degradation of plastic is a long period process, much longer than the life of many living beings.

To deal with plastic, different countries have done research and implemented different strategies and instruments, such as bans, plasttax, voluntary campaigns and many others. Scientists have widely used life cycle assessment as a tool for choosing the best alternative for carry bags and have achieved quite good results. For my research I used the same tool and succeeded in realizing the main purpose which was to identify the most sustainable type of plastic bag. It turned out that manufacturing of biodegradable vest-bags at LLC "Polymer" is more sustainable and environmentally friendly. There are several benefits to producing these bags, primarily for the enterprise and generally for the environment. Firstly, LLC "Polymer" will continue to lead on the polymers market in the Vinnitsa region and expand sales throughout in Ukraine and possibly abroad. Secondly, biodegradable bags make less impact on the environment, which is important in the over-polluted modern world.

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Appendix A

Guider for semi-structured interview #1 with Mukola Lubenko

Section 1.General Issues

- What is the history of the enterprise development?
- What reasons can you name were and are the most important for successful work?
- Plans for future.

Section 2. Production:

- Produced kinds of the film.
- Are biodegradable bags produced only specific customer?

Section 3. Recourses for vest-bags production:

- Required materials for film production.
- Main requirements for pattern printing.
- Color of the film.

Section 4. Transport

- Where do you buy materials and recourses?
- Type of vehicle used to transport materials.
- Kind of benzene or other fuel used by vehicle.

Section 5. Emissions and byproducts:

- Emission during manufacturing process.
- What is the amount of the emitted substances?
- What are you doing with scraps?

Appendix B

Guider for semi-structured interview #2 with Vitalij Klischuk

Conventional bags

- How many kilograms of HDPE and LDPE are used for production of 1000 bags?
- Name the emissions and amount to the air during film production.
- How to you make printing of patterns?
- Are any emissions of harmful substances produced?

Biodegradable bags

- Which is secret of your biodegradable bags?
- Which kind of additive is used? And how much?

All next questions were similar to that which I asked about conventional bags.