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Sustainable Packaging Logistics

The link between green packaging and sustainability in supply chain

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Abstract

Packaging is often considered as an ephemeral product due to its intended role in the product system. However, packaging plays a vital role in supporting and promoting improvements and innovation in the sustainable supply chain. In this context, the concern was that packaging companies were struggling to achieve green sustainability in the supply chain through eco-friendly packaging designs.

The objective of this study was to analyze the link between green packaging and sustainability in supply chain in order to provide packaging companies with a comprehensive perspective of adopting a sustainable supply chain in terms of environmental, economic and social development. It was hoped that the information gained from this study could be generalized into a standard guideline for future firms so that they could reflect on themselves to gain sustainability successfully by adopting green packaging in the circular economy.

The quantitative research approach was used to achieve the objectives. Five pairs of food packaging and an online survey were conducted to guarantee the validity and reliability of the results. The outcome retrieved from both comparison and online survey was transcribed and analyzed with the content analysis.

The results could be used by companies that wish to pursue a similar path to continue analyzing sustainable packaging logistics. Due to the small sample size, the results should not be used as a shred of standard evidence. Moreover, companies should consider the given advice to achieve a similar outcome.

Keywords/tags (subjects) Green packaging, Eco-costs, Reverse Logistics, Environmental Sustainability, Economic Sustainability, Social Development, Packaging, Circular Economy

Miscellaneous (Confidential information)

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Term and Abbreviation

CSR	Corporate Social Responsibility
EEA	European Economic Area
EFSA	European Food Safety Authority
EU	European Union
EURL-CM als	European Reference Laboratory for Food Contact Materi-
FCMs	Food Contact Materials
FMCG	Fast moving consumer goods
LCA	Life cycle assessment
MW	Molecular weight
OM	Overall migration
PLC	Product life cycle
Pro Europe	Packaging Recovery Organization Europe
QR code	Quick Response code
RFID	Radio frequency identification technology

SD	Sustainable Development
SPL	Sustainable Packaging Logistics
USDA	United States Department of Agriculture
TBL	Triple Bottom Line

1 Introduction

Keywords such as “food”, “waste management”,” carbon footprint” and “sustainable packaging” relate to a variety of new articles, publications and annual reports when typed into the search bar. Nowadays, the Earth is gradually warming up, and humans are at least partially responsible for that. For this reason, the topic of sustainable packaging has been of concern to all stakeholders in seeking innovative, ecological and user-friendly packaging solutions. Awareness of this issue has risen over the last decade, and a large number of recyclable materials has been developed as a commitment of global companies to reduce the climate impact of packaging.

Climate change has changed from something that only specialist atmosphere experts are concerned about, into a topic on the daily agenda for politicians and economists, as this issue taps into every individual’s life. Besides, it also affects companies in multiple ways from different aspects such as the presentation of new products to customers, resources apportionment and recycling products. However, materials also play a crucial part in influencing logistics, waste management, cost structure and the environment as explained further in other chapters.

On average, packaging accounts for about 5% of the energy used in the life cycle of a food product making it a significant source of greenhouse gas emissions. Moreover, this percentage can rise depending on the products’ characteristics and requirement in the future because new products keep penetrating market every day. Therefore, for some products, the packaging used has an even bigger impact on the climate change than the fuel used to ship it to market.

To establish the field further, the purpose of this study was twofold. Firstly, the purpose was to offer a comprehensive review of the packaging field including a brief history, all types of packaging functions and food packaging regulations in Europe, especially in Finland. Secondly, the purpose was to offer a conceptual framework by sum-

marizing the research in this field in two parts. The first part concentrated on characterizing the main aspects associated with sustainable packaging logistics in terms of environmental, economic and social development. The second part focused on analyzing the sustainability and competitiveness in the supply chain through eco-costs created by green packaging.

Nowadays, modern enterprises do not use package only as a means of covering for their products, they have developed it as a marketing tool which enables brands to communicate with customers. Similar to any good design, packaging not only tells a story but also a sensual experience, literally engaging consumers through sight, touch and sound. In particular, packaging contains not only the essential information of a product including ingredients, nutrition information, a barcode, an expiration date or batch number and so on but also the brand of that product. All of these details facilitate consumers perceive what the enclosed product is for, how it should be used, what age is appropriate to for using, and most significantly if they should purchase the product or not. Indeed, most companies do not focus on communicating with their customers about packaging materials. Instead of that, they concentrated on the brand and content of the packaging. Thus, it would be ideal if sustainability, energy and waste management were on top of the designer's mind when designing a new package for both new and old products, especially when global warming is becoming a sensitive topic in every daily agenda.

2 Methodology

In order to identify and choose the most appropriate research method for this study, it was important to understand the similarities and differences between them. Choosing the most efficient and suitable one, indeed, will help a researcher achieve the outlined aim of a study effectively. The selection of research methods should be focused on what kind of data needs to be collected in order to obtain the necessary information for the research problems. (Kananen 2015, 65; Walliman 2011, 92.)

The following chapters first explain the differences between qualitative and quantitative data and research methods. What follows is an explanation of which methods were chosen for this specific study and descriptions of these methods. Furthermore, the chapters aim to explain and justify the choices made. The chapters focus on the methods of internet surveys that were all used as a means for data collection in this study. (Kananen 2015, 65; Walliman 2011, 92.)

2.1 Qualitative and quantitative research methods

It is universally acknowledged that data are often divided into two different categories which are qualitative and quantitative data based on its characteristics. The significant factor that differentiates quantitative data from qualitative data is that quantitative data is measurable, as it is often in the form of numbers, whereas qualitative data cannot be quantified since it takes the form of words mostly describing abstract concepts, such as judgement, emotions, ideas and beliefs. (Goodson & Phillimore 2004, 3; Walliman 2011, 71-73.)

Just as data is divided into qualitative and quantitative variety, so are different types of research methods. It is typical to choose between quantitative and qualitative research methods, but it is also possible for researchers to combine both for use in a single research project depending on the kind of study and its methodological foundation. According to Allwood (2011, 302), three major distinctions between qualitative and quantitative research are the form of data collection, analysis and the presentation. The basic premise of this chapter is understanding the similarities and differences between qualitative and quantitative research. (Kananen 2015, 67; Kuada 2012, 91.)

Qualitative research is a method used for forming a better understanding of the topic and finding an answer to the question “What is this phenomenon all about?”. Qualitative research is designed to enable researchers to gain a deeper understanding of

the topic, especially when there is no existing information, theories, models or research available. (Kananen 2011, 37.).

Qualitative research is flexible, and it is not necessary to follow strict rules on the research path. Qualitative data sources include observation and participant observation (fieldwork), interviews and questionnaires, documents and texts, and the researcher's impressions and reactions (Myers, 2009).

Quantitative research requires accurate questions because the research can easily miss something important during the data collection if questions are not correctly formed. Moreover, all the stages, as well as the rules, have to be followed strictly for the accuracy and reliability of the results. Therefore, the researcher needs to have knowledge of the existing theories before starting to collect data for analysis. Otherwise, there is a risk that the researcher has been focusing on completely wrong issues in the questions. The questions themselves can be wrong or the options for answering might not include the relevant answer at all. In this case, the whole research can miss the main point. As a result, the costs of the fieldwork will be doubled. (Kananen 2011, 73). A summary of the differences between those two research methods can be seen in Table 1.

Table 1.Qualitative vs. quantitative research. (Adapted from: Denscombe 2003)

	Qualitative research	Quantitative research
The unit for analysis	Words	Numbers
Researcher's interpretation of the phenomenon	Descriptive	Analytic
Scale of research	Rather small-scale	Rather large-scale

Focus of research	Holistic approach	Specific focus
The Connection with researcher	Researcher involvement	Researcher detachment
Research design	Emergent	Predetermined

2.1.1 Why does quantitative research fit the study?

The quantitative research approach was chosen for this bachelor's thesis because it was considered extremely well-suited for the author's purposes. Moreover, the selection between qualitative and quantitative was clear from the beginning.

The study was based on the quantitative research of literature about the link between green packaging and sustainable supply chain in terms of economic, environmental and social development for forming a better understanding of the topic. Applying this method to this bachelor's thesis was hoped to offer an opportunity to achieve a deeper understanding of the topic.

2.1.2 Research Question and Aim of the study

The primary objective of this research was to analyze the potential impact on efficiency of adopting sustainable packaging in terms of environmental, economic and social development. In this regard, the author of this study shared the view that efficiency and sustainability are compatible, and he hoped to provide the readers with a better understanding of how sustainable packages influence the environment nowadays.

The research questions of this bachelor's thesis were:

1. How does green packaging relate to sustainability in the supply chain?
2. How does green packaging contribute sustainable value to the supply chain and to consumers?
3. How do consumers see the value in green packages?

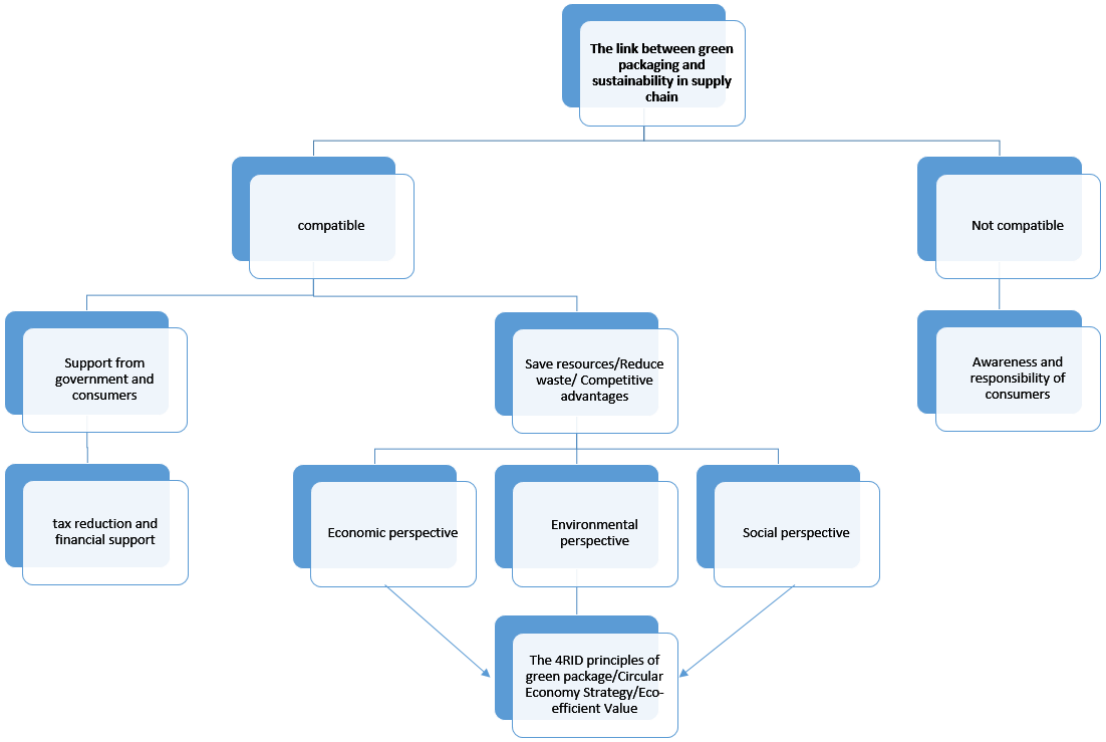

Figure 1.Research Question Framework.

The research questions were derived from the fact that the majority of packages nowadays are not suitable for all the products that they are used to cover. Every product has specific requirements for packaging so that proper package materials play vital parts in performing on a higher level to sustain its desired condition. Moreover, climate change has been the subject of wide debate that extreme weather is occurring with significantly increased frequency from man-made causes. Since the onset of the sustainability era, sustainable packaging has become one of the top influencers of purchase decisions. According to Anthony (2014), it is not that consumers are opposed to the notion of sustainable packaging but for the most part, they

are not willing to sacrifice for it in terms of pricing, performance and convenience. Therefore, the study was created to provide all readers with sufficient information including the history of packaging, regulations regarding to materials that come to contact with food, product marking and symbols used, plus an adequate analysis of sustainable packaging logistics that is now the key driver of innovation and its link between sustainability and competitiveness in the supply chain.

3 Packaging in brief

3.1 History of Packaging

In ancient times, human beings were self-sufficient in that they spent most of their time on gathering, hunting and consuming food where it was found in nature. However, as the civilization grew along with an increasing demand of preserving food, primitive humans began to pack food for longer shelf life by taking advantage of natural materials, such as tree leaves, bamboo, lotus leaves, palm leaves, gourds, coconut shells, seashells and animal skin. Later on, with the discovery of new materials such as fabrics, ceramics, metals, lacquerware, wood ware, jade ware, and certain types of paper, the packaging industry transformed itself into a higher level. Significantly, the invention of steam engines marked the beginning of the Industrial Revolution in the eighteenth century. The Industrial Revolution created tremendous changes in packaging in the history of mankind. Indeed, the whole concept of packaging and the consumption patterns worldwide were extensively changed by the manufacturing technology. An illustration of a brief history of packaging can be found in Figure 2.

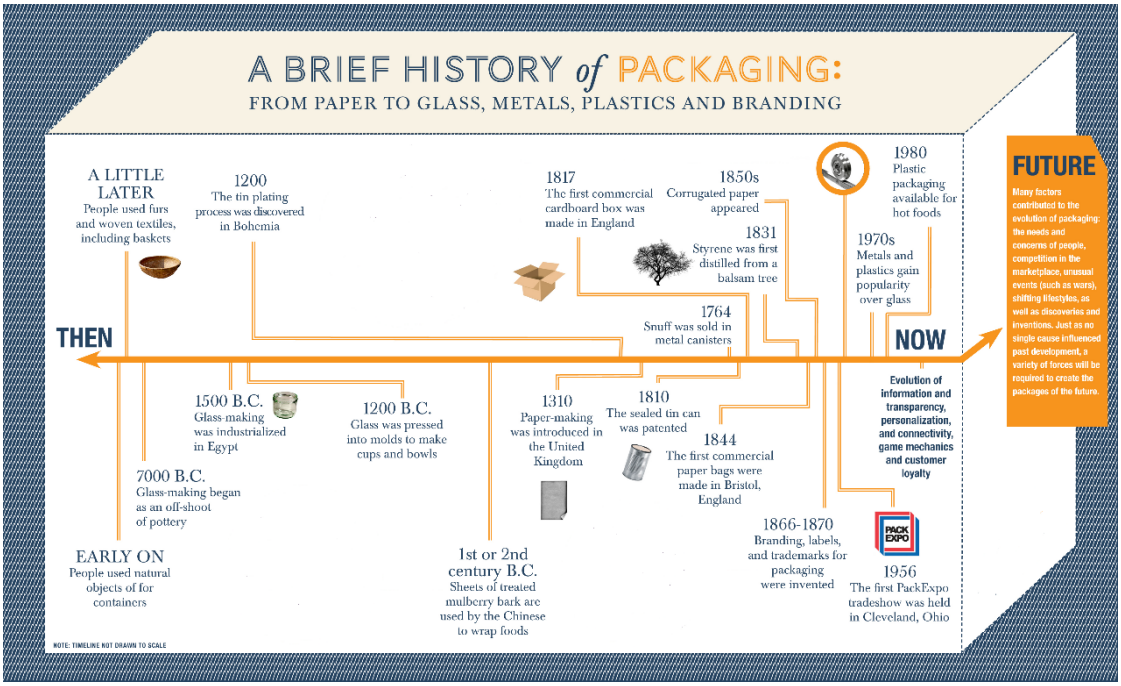

Figure 2.History of Packaging. (Adapted from Bishop-Wisecarver 2012)

3.2 Packaging Function

Packaging performs a series of disparate tasks, such as protecting the content inside from contamination and spoilage, making the final product easier to transport and store as well as providing a uniform measuring of contents (Hine, 1995). From the author's this statement implies that if a package is designed to fulfil its function, it must endure all primary functions including containment, protection, convenience and communication. Moreover, several additional functions, such selling, promotion, and environmental responsibility, should be taken into consideration simultaneously during the packaging design and development process.

The food packaging industry has made the advertising business effective and wide-ranging distribution possible by standardizing brands. For manufacturers, packages are not used only as a means of covering for the product, they are a way of life. According to Robertson (2012 4), packages not only can effectively communicate the

true value that a product offers but they are also equally potent symbols of wastefulness once the product is gone. However, it often occurs that most packages found on retailers' shelves lack in one or more of the functions' categories. One of the functions that are rarely mentioned in the packaging is sustainability. Especially with the current state of the environment which has been turned into a topic on the daily agenda, this function should be at the top of manufacturers' priorities in order to create less waste and enable consumers to recycle or reuse those packages after consuming or unboxing their products.

3.2.1 Containment

The term "containment" means, simply, to contain goods and prevent them from spillage and loss. This function of packaging is so obvious that it is easily overlooked. However, compared to other packaging functions, the "containment" function plays an extremely vital role in protecting the final products because goods are likely to be lost or contaminated by the environment. Consequently, without the "containment" function, product loss and pollution would be widespread (Robertson 2012, 2). All products must be contained for delivery from the point of production to the final destination. Even products that consist of chemical hazards or multiple parts, such as bulk products or a bulk cement rail wagon, must be contained to function successfully.

3.2.2 Protection

The package's defensive feature prevents all external forces to interfere with the product inside. The protection function is often regarded as the primary function of packaging to protect its content from both physical damage and environmental influences such as water, light, gases, odors, microorganisms, vibration, compressive forces, etc.

Food during the time elapsed between the production line and ultimate consumption has a high potential to be exposed to various hazards which make the food unavailable for consumption or significantly affect the quality of food. For this reason, the protection function makes a major contribution to protecting and preserving products from a myriad of hazards while being moved from one place to another on numerous occasions each day in any modern society (Robertson 2012, 3).

3.2.3 Preservation

The primary preservation function of packaging is to keep the products in a controlled environment so that they retain the quality and safety of use for a longer period without affecting the quality of food. The term “preservation” is often taken into account especially when dealing with food products, pharmaceuticals and other perishable products. A good packaging system should protect the contents from changing their nature without affecting the quality and under no circumstances may various types of hazards happen during the distribution chain.

3.2.4 Utility

The utility function of packaging is used to describe the convenience of packages. Modern industrialized societies have brought about tremendous changes that consumers demand from products so that they fit into their lifestyles and the packaging industry has had to respond to those changes. As a result, the utility function of packaging should encompass all the packaging attributes that provide added value and convenience to the users of the product or package (Clark, Jung, & Lamsal 2014, 250).

According to Tanner and Raymond (2010, 68-72), customers make decision while shopping based on several stages, and one of them is the size of the product that they will buy and its convenience. Furthermore, the demand for a wide variety of food and drink at outdoor functions, such as sports events or backyard BBQ parties

has created a huge demand for greater convenience in household products. Therefore, the design of recent products has changed gradually to increase convenience including foods that are pre-prepared and that can be cooked or reheated in a very short time (Robertson 2012, 3).

According to McAdam (2012, 10-12), customers are much more interested in what the offer does for them than they are in what the offering does. For this reason, the packaging plays an extremely important role in meeting the customers' requirements for convenience. To give an illustration of what this means, we could look at the case of egg packaging which can be found easily in any markets. When a mother needs to buy eggs for a 6-member family that loves omelets, it is likely that she would choose a package of 12 eggs instead of a package of 6 eggs. The critical reason for this is that she may need another 6 eggs to make another dish without wasting time to go shopping in the market. However, a package of 6 eggs or more could be an optimal solution for people living alone or married couples without children for better convenience without being afraid of producing food waste. Another example of a convenient package is that when a customer purchases milk for immediate consumption, they will choose a re-sealable package which has a plastic lid on the upper part of the package rather than purchase an un-resealable package since they may continue drinking in a period of several hours.

3.3 Packaging as a Source of Information

3.3.1 Tracking information

It is universally acknowledged that there are two forms of automated data collection, which are barcodes and RFID systems, have been used for managing inventory and tracking purchase patterns for decades. Although their nature which is about carrying product information is similar, they are completely different from each other.

A barcode is a visual representation of data that needs a scanner with a beam of light to read the black and white lines to collect information. According to Alexander (2018), the black and white lines of a barcode will be decoded and turned into text by the scanner. After that, the information will be sent directly to a database system for analysis. Another key thing to remember is that every line of the code must be scanned precisely so that scanners can read and transmit the data accurately. Barcoding requires a person to physically scan each item individually. On the other hand, RFID systems show their efficiency by being cable of scanning multiple items at once.

RFID stands for radio-frequency identification, which uses radio waves to transmit information from RFID tags to an RFID reader. While RFID is truly efficient with high productivity, the system may sacrifice accuracy. Barcodes can read codes regardless of the substance, whereas the RFID system will decrease capabilities for reading tags when operated near metals or liquids.

3.3.2 Product information

Product information usually consists of different contents such as the name of the product, imagery, required marks and temporary content for legal reasons. There are several regulations on product information by government and some of them have to be on the package including the country of origin, manufacturer, nutrition information, association marks and barcodes. Each product requires different information based on its nature and purpose of the manufacturer. For instance, the labels on clothes indicating how to treat garments during washing and drying are strictly regulated in the textile industry.

Nowadays, consumers are gradually conscious of the nutritional information on packaged foods and the origin of ingredients used in the preparation, manufacture or handling of the food. Furthermore, the food manufacturers also opt to put a health star rating on the front of their products' packages in New Zealand. Therefore, not only food manufacturers but also other manufacturers of any industry chose to meet

the customers' requirements by attaching and printing QR codes that can be scanned by any kind of smartphone. All detailed production's description will automatically appear on the screen when consumers scan these codes. This technology enables consumers to access more data about the products they are willing to purchase without the assistance of store workers.

3.3.3 Marketing tool

According to Vetrova (2019), eye-catching design and high-quality printing attract consumers and differentiate a brand from other competitors in the market. To put it another way, the information contained on food packaging is one of the critical factors significantly influencing the opinion of consumers about the product. It is irrefutable that the packaging industry offers the marketing industry a huge opportunity to positively impact a brand's image by communicating with consumers through packaging design. Indeed, good marketing communication associating with a perfect graphic design will encourage potential consumers to buy the product and come back for more. To give an illustration of what I mean, let's look at the case of Pringles which is one of the most famous American companies providing crunch and delicious flavors of stackable snack chips. The major distinction between Pringles companies and their competitors is the packaging. Instead of using traditional plastic or foil bags, Pringles companies decided to innovate the appearance into the cylindrical shape of the canister along with the icon "Mr.Pringles" which is the single most recognizable graphic element of the package. Furthermore, the company also follows strict color mode for its product lines for easier recognition. (See Figure 2)

Figure 3.Pringles Packaging. (Adapted from Hare 2019).

Another key thing to remember is that color is one of the methods used in defining a subcategory of products. For instance, let's take a look at the milk label color. It is widely acknowledged that there are various types of milk which is from skim milk to whole milk and everything in between. Consumers can tell them apart easily by the color of caps and labels while they are shopping. The blue package means low-fat milk, while red package suggests the full fat.

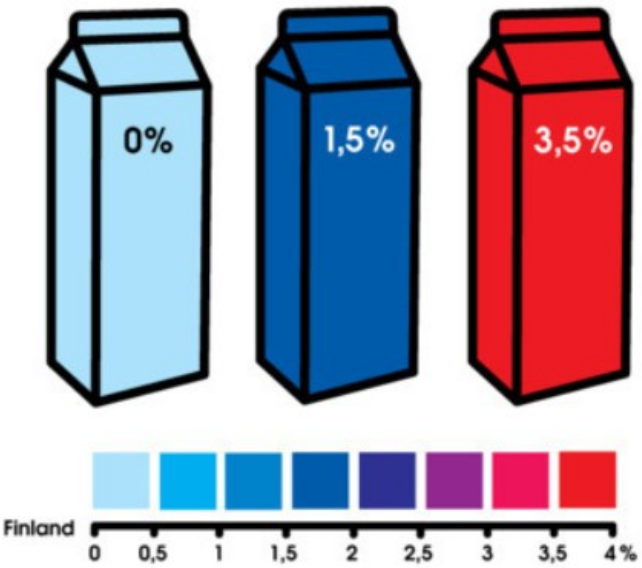

Figure 4.Color of milk packaging versus fat content in Finland. (Adapted from Stromman 2011, 47)

3.4 Labelling

Labelling is regulated to help consumers obtain the complete information and make the right decision in choosing products based on diet, allergies, personal taste or cost. Every customer has the right to know about the food they have bought matches the description given on the label. The information on labels must be precise, clear and easy to read and understand by the consumers, in order to protect their interests and health. For instance, quantity information, e-mark, nutrition information, country of origin, etc. The following chapters will explain more about these specifications.

3.4.1 Nutrition information

Nutritional values of the product are necessary information that labels should content. In essence, the manufacturers should provide consumers with complete infor-

mation on the value of energy and different kinds of nutrients. This specific nutritional information should be presented in a table in the same field of product vision, which is clear, easy to read and understand (see Figure 3).

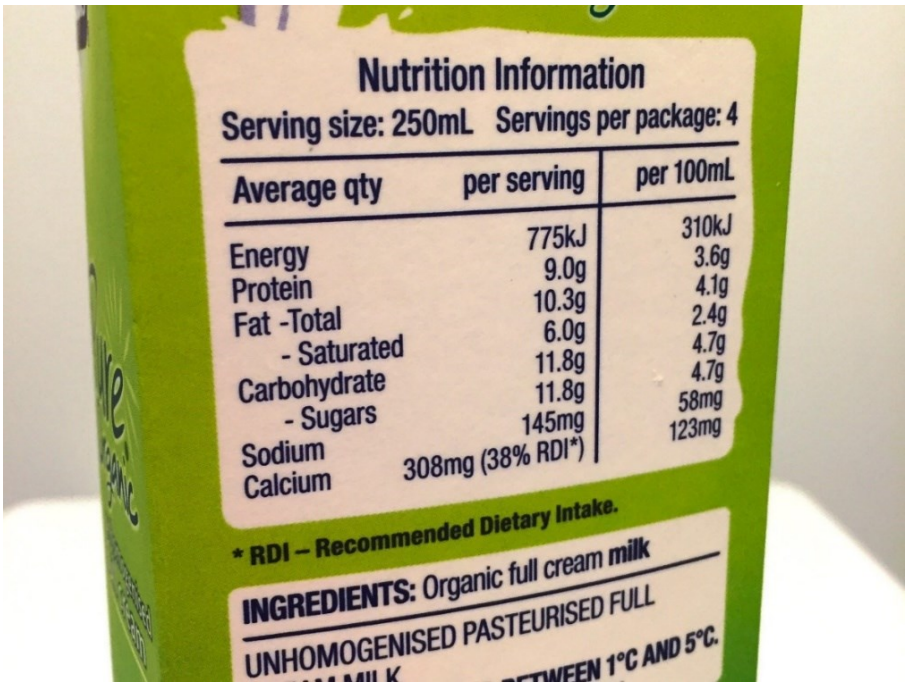

Figure 5.Nutrition Information. (Adapted from Saxelby 2018)

The critical role of nutrition information is helping consumers become more knowledgeable about their everyday diet and make better choices about what are choosing to purchase.

3.4.2 Quantity information

The net quantity statement must be put in mass weight units such as grams, kilograms, milliliters or liters on the label of the package by the manufactures. The net quantity must be placed close to the name of the food and in lines parallel with the base of the package so that consumers can see all this information at the same time. This also applies to alcoholic drinks. However, there are some products which are not

necessary to show the weight or volume. To give an illustration of what I mean, let's look at the case of bread roll package in a bakery store. The consumers can see the number of items inside the packaging so that the net quantity in mass weight units does not apply to some typical products.

3.4.3 The e-mark

According to National Measurement & Regulation Office (2015), the 'e' symbol or the 'e-mark' placed on a label means that the product can be exported to AA European Economic Area (EEA) markets. As such, it acts as a metrological passport throughout all EAA markets without having to meet weights, requirements and measures of all European countries.

Figure 6. E-mark. (Adapted from Ivanko 2017)

3.5 Marking

Food packaging symbols are all over products, but not every consumer knows what they are or understands the essence of them. Therefore, the most common packaging symbols in EU food products will be explained precisely in this chapter.

The first mark is the universal labelling symbol, indicating that the materials used for food packaging have been previously tested to avoid harmful impacts on human health. This wine glass and fork icon mean that packaging is suitable for food use. It is

mostly made of plastic materials, however other materials are also able to carry this symbol in EU such as cling film, ceramic, etc. The specific regulations may vary from one country to another. In the EU, the Commission Regulation (EC) 1935/2004 is the main reference for all food contact materials. According to the Commission Regulation, substances present in FCMs shall not migrate into food in concentration that may endanger human health. Moreover, unacceptable changes in the composition of the food, as well as deterioration in organoleptic properties may not be exposed by food packaging.

Figure 7.Food Contact Material Symbol. (Adapted from Mo 2020)

The Green Dot trademark for Europe is licensed by Packaging Recovery Organization Europe, which was founded in Germany in 1995. They use the registered trademark “The Green Dot” as a financing symbol which means that a financial contribution has been paid to the national packaging recovery organization for the manufacturing of each package. The vital role of PRO Europe is to ensure the most economically efficient and ecologically sustainable recovery and recycling of packaging waste.

Figure 8.The Green Dot Symbol. (Adapted from Pro Europe 2017)

BioPreferred is a registered trademark used by the United States Department of Agriculture (USDA) to help consumers obtain the level of bio-content required in product and packaging. The USA government aimed to promote the purchase of bio-based products and encourage companies to use renewable resources as alternatives to petroleum such as synthetic polymers. Moreover, the core goal of the USDA BioPreferrred program is to better manage the atmospheric carbon cycle.

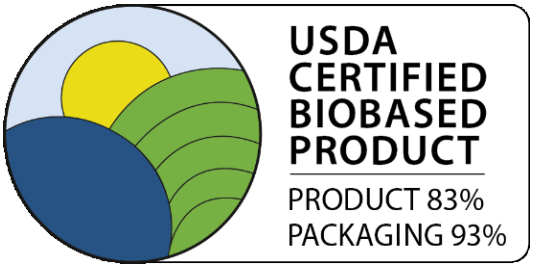

Figure 9. BioPreferred Trademark. (Adapted from USDA 2020)

The Tidy man symbol is one of the most universal symbols placed on food packaging all around the world. The symbol was developed by Tidy up Britain charity organization in the United Kingdom. The core goal of this symbol is to remind consumers to

be a good citizen by disposing of the packaging in the most appropriate manner. According to Carter (2017), the Tidy man was first published on bins and packaging in the 1960s and fast became a universally international recognized symbol since then.

Figure 10.Tidyman Symbol. (Adapted from Keep Britain Tidy 2020)

The Mobius Loop or the recycling triangle is known internationally as recycling symbol no matter it has the unfamiliar name. This symbol means that the packaging or the product itself is capable of being recycled if placed in the correct recycling collection system.

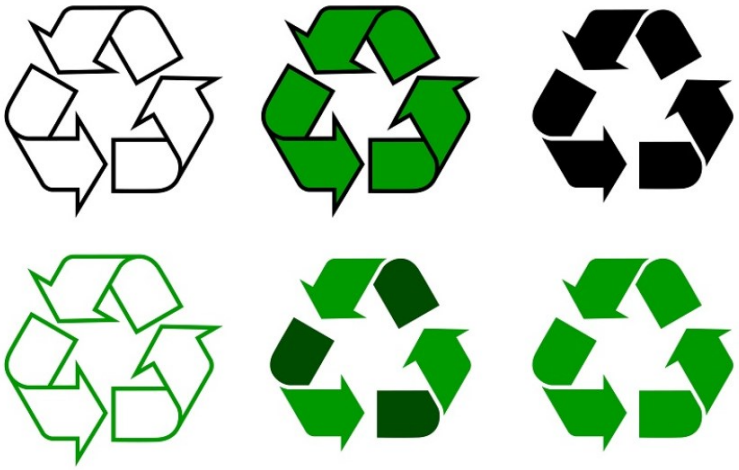

Figure 11.Möbius Loop Symbol for Recycling.

Another key thing to remember is that the presence of the Mobius Loop on the package not only means that the product is recyclable but also indicates how much of that packaging is made from recycled sources. To give an illustration of what I meant, let's look at figure 10 below. The percentage figure 85% means that 85% of the whole package was made from recycled material.

Figure 12.Möbius Loop Symbol with a percentage figure.

What's more, if there is a chasing arrow and a number which ranges from one to seven in the middle of that symbol at the bottom of the packaging, consumers may identify the type of plastic resin used to make the item. As a result, all the packaging will be recycled in the most economically efficient and ecologically manner. However, if consumers do not have complete knowledge of these "Resin Identification Code" and incidentally toss an item that local recycling program does not accept, in consequence, they have potentially ruined a whole recycling batch.

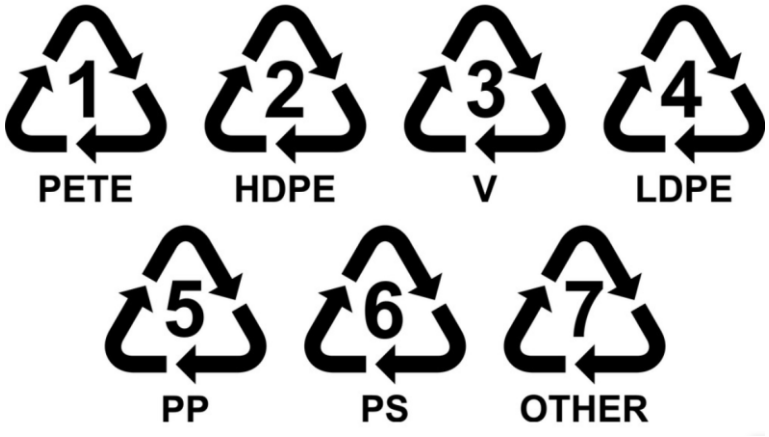

Figure 13.Plastic Resin Codes. (Adapted from Seaman 2012)

The summary of differences between resin identification codes can be seen in Table 2 below.

Table 2.Resin Identification Codes. (Adapted from Seaman 2012)

Resin code	Abbreviation and Polymer name	Product Applications
1	PETE or PET: Polyethylene	• Soft drink bottles • Carpet • Strapping • Fruit juice container • Mineral water

	Terephthalate	
2	HDPE: High-density Polyethylene	• Grocery bags • Milk jugs • Recycling bins • Laundry Detergents • Shampoo bottles • Plastic lumber • Agriculture pipe
3	PVC: Polyvinyl Chloride	• Food foils • Trays for fruit • Plastic packing • Shower curtains • Children's toys
4	LDPE: Low-density Polyethylene	• Crushed bottles • Shopping bags • Highly-resistant sacks • Dispensing bottles • Wash bottles • Various moulded laboratory equipment
5	PP: Polypropylene	• Furniture • Luggage • Bumpers • External borders of cars • Industrial fibers • Food containers • Dishware
6	PS: Polystyrene	• Toys • Hard packing • Refrigerator trays • Cosmetic bags • Costume Jewellery • CD cases • Plastic utensils • Desk accessories
7	Other or O: Other Plastics	• Nylon • Acrylic • Polycarbonate • Multilayer combinations of different plastics • Polyactic fibers • Fiberglass

The seeding logo, which is a registered trademark owned by European Bioplastics, is used to identify that a product is certified industrially compostable in accordance with European standard EN 13432/14955. When the respective product is successfully certified by the independent certifiers DIN CERTCO from Germany or TÜV AUSTRIA from Belgium, it will fully biodegrade in an industrial plant under controlled conditions within a few weeks.

Figure 14.Compostable symbol. (Adapted from European Bioplastics 2020)

3.6 Regulation in Packaging

3.6.1 Migration

It is irrefutable that food packaging can be a source of chemical food contaminants. Migration is the diffusion of chemical contaminants initially present in the packaging material into food. Various factors are affecting the extent of migration such as temperature, nature of the food, concentration of substances, storage time, size of the packaging in proportion to the foodstuff volume and so on. The chemical contaminants have different migrations of substances from food packaging material to food depending on the chemical structure. For this reason, when any materials are in contact with food, the migration of particles into food is inevitable.

There a numerous low MW plastics that can migrate including plasticizers, antioxidants, monomers, etc. These substances may migrate from the outside through the packaging. To give an illustration of what I meant, let's look at the case of dry food packaging, the printing inks are potentially capable of migrating through the paper board or plastic packaging into dry foods. According to Robertson (2012, 122), this diffusion of chemical substances may result in a loss of food quality due to significant changes of flavor and color. Even more, this can also cause severe damages such as the occurrence of toxic chemicals or microbial pathogens which could produce negative health implications to the human after prolonged exposure at low levels (Ardic, Kahve, & Duran 2015, 163).

3.6.2 EU regulation

EU legislation provides for the binding rules which enterprises must comply to guarantee the safety of FCMS and to facilitate the free movement of goods. Moreover, the European Food Safety Authority (EFSA) is a separate organization that is mainly responsible for evaluating FCM's safety and examining emerging issues in food production (EFSA, 2020). Furthermore, the European Reference Laboratory for Food Contact Materials (EURL-CM) plays a vital role in maintaining scientific knowledge and technical competence in testing methods.

According to the European Parliament and of the Council (2014), the regulation (EC) No 1935/2004 on materials and articles intended to come into contact with food and repealing Directives 80/590/EEC and 89/109/EEC aim to secure a high level of protection of human health and the interests of consumers.

According to the European Parliament and the Council's framework, the basic Community legislation covers all food contact materials and no FCMs shall "transfer constituents into food at levels that endanger human health" (Art. 3 EC 1935/2004). General requirements on materials and articles intended to come into contact with food and repealing Directives are defined below:

> "1. Materials and articles, including active and intelligent materials and articles, shall be manufactured in compliance with good manufacturing practice so that, under normal or foreseeable conditions of use, they do not transfer their constituents to food in quantities which could:
>
> (a) endanger human health; or
> (b) bring about an unacceptable change in the composition of the food; or
> (c) bring about a deterioration in the organoleptic characteristics thereof.
> 2. The labelling, advertising and presentation, of a material or article shall not mislead the consumers." (Parliament and Council Regulation (EC) 1935/2004 of 27 October 2004)

In general, active and smart packaging is also regulated under the framework regulation EC 1935/2004. In particular, active packaging means active food contact materials may absorb or release substances into food that are regulated as food additives or food flavoring to enhance the quality of packaged food or extend its shelf life. Besides, smart packaging means intelligent food contact materials are capable of monitoring the condition of packaged food flexibly based on the surrounding environment. In accordance with the framework regulation EC 450/2009, additional safety requirements for active and smart packaging will be established as below:

> "a) 'active materials and articles' means materials and articles that are intended to extend the shelf-life or to maintain or improve the condition of packaged food; they are designed to deliberately incorporate components that would release or absorb substances into or from the packaged food or the environment surrounding the food;
>
> b) 'intelligent materials and articles' means materials and articles which monitor the condition of packaged food or the environment surrounding food." (Commission Regulation (EC) No 450/2009 of 29 May 2009).

All materials and chemical substances that have potential chances to cause harm to human health are also abolished by the EU. However, not all packaging material-specific regulations have been adopted under European community law. For instance, there is no specific regulation for printing ink, waxes, paper and resins in accordance with the framework regulation EC 1895/2005. The scope of this regulation for materials and articles is as follows:

> "(a) materials and articles made of any type of plastics;
>
> (b) materials and articles covered by surface coating; and
>
> (c) adhesives." (Commission Regulation (EC) No 1895/2005 of 18 November 2005)

In practice, the European Parliament and of the Council also established some regulations related to packaging and packaging waste. According to the European Parliament and the Council's framework, the regulation 94/62/EC on packaging and packaging waste required the Member States or the Treaty to minimize the environmental impact of packaging waste and define the essential requirements governing the reusable and recyclable nature of packaging. Moreover, an environmental point of view recycling of packaging should be considered as a vital role in reducing the consumption of energy and the final disposal of waste as well. Similarly, the process of disposing of packaging waste shall be carried out in an environmentally sound manner taken by the Member States in accordance with the objectives of this Directive. The objectives of this Directive that Member State shall comply with are defined below:

> "1. In order to comply with the objectives of this Directive, Member States shall take the necessary measures to attain the following targets covering the whole of their territory:

(a) No later than 30 June 2001 between 50% as a minimum and 65% as a maximum by weight of packaging waste will be recovered or incinerated at waste incineration plants with energy recovery;

(b) No later than 31 December 2008 60 % as a minimum by weight of packaging waste will be recovered or incinerated at waste incineration plants with energy recovery;

(c) No later than 30 June 2001 between 25 % as a minimum and 45 % as a maximum by weight of the totality of packaging materials contained in packaging waste will be recycled with a minimum of 15 % by weight for each packaging material;

(d) No later than 31 December 2008 between 55 % as a minimum and 80 % as a maximum by weight of packaging waste will be recycled;

(e) No later than 31 December 2008 the following minimum recycling targets for materials contained in packaging waste will be attained:
   i. 60 % by weight for glass;
   ii. 60 % by weight for paper and board;
   iii. 50 % by weight for metals;
   iv. 22,5 % by weight for plastics, counting exclusively material that is recycled back into plastics;
   v. 15 % by weight for wood." (EUROPEAN PARLIAMENT AND COUNCIL DIRECTIVE 94/62/EC of 20 December 1994 on packaging and packaging waste)

3.6.3 Finland regulation

In Finland, packaging and packaging waste must meet the basic requirements within the scope of producer responsibility. Producer responsibility means that companies that manufactured the product or imported the packaged product to Finland are obliged to handle the waste management when the packaging is removed from use. Furthermore, several substances are limited to exist in packaging such as cadmium, lead, mercury and hexavalent chromium. The maximum weight of these chemical substances restricted in packaging per kilogram can be contained is 100 milligrams. However, in accordance with Commission Decision on plastic crates and plastic pallets 2009/292/EC and Commission Decision on glass packaging 2001/171/EC, this rule

does not apply to glass packaging or plastic crates or pallets used in a closed and controlled product cycle because these substances may contain more heavy metals.

Labelling of the packaging is not compulsory in Finland. Indeed, if a company wants to place labelling of the packaging for the identification of its materials, the marking shall be made in accordance with Annex 3 of the Finnish Government Decree on Packaging and Packaging Waste (518/2014). Another key thing to remember, the marking shall be visible and easy to read (Finnish Government Decree on Packaging and Packaging Waste, 2014).

Finland also harmonized all the EU-legislation of food contact materials to ensure the safety of human health. Indeed, all operation of food contact material operators including manufacturers, importers, suppliers and wholesalers must be notified to the Finnish Food Authority in accordance with the Finnish Food Act (23/2006). The legislation on food contact materials in the EU and Finland are presented in figure 13 below.

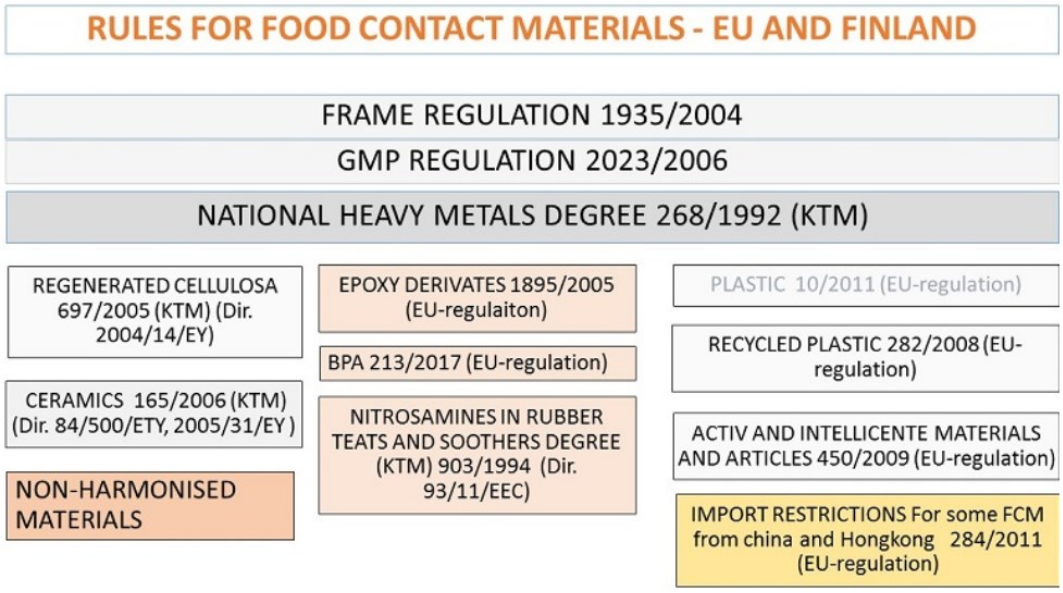

Figure 15.Rules for food contact materials-EU and Finland. (Adapted from Finnish Food Authority 2020)

As mentioned above, the framework regulation EC 1935/2004 and regulation EC 2023/2006 give a specific mention to materials and articles intended to come into contact with food and good manufacturing practices. Beside Plastic Regulation 10/2011, Recycled Plastics Regulation 282/2008 and Regulation 450/2009 on active and intelligent materials governed by EU community laws, Decree 165/2006 of the Ministry of Trade and Industry, and Regenerated Cellulose Directive 2004/14/EC by Decree 697/2005 of the Ministry of Trade and Industry also implemented Ceramics Directives 84/500/EEC and 2005/31/EC in 2005 (Finnish Food Authority, 2020).

4 Green Packaging and Sustainable Packaging Logistics

The increasingly turbulent and volatile markets plus the growing concerns about the climate change have created massive pressures on enterprises in the food packaging industry especially regarding the competitiveness of supply chains. Particularly, several situations that have had a significant effect on the competitiveness of supply chains are the globalization of supplies and sale, the increased costs of raw materials, the life cycle of products, renewable sources and waste management.

These situations have led attracting logistics enterprises' immediate attention to this matter. In fact, the "Kaizen" or "Lean Management" method has been taken into account precisely to ensure maximum performance in logistics activities such as transportation, handling, storage and production, or an appropriate solution to waste management. Simultaneously, different stakeholders including consumers, shareholders, public administrations and unions have started to show their corporate interest in green packaging and efficiency in sustainable supply chain management in the recent years.

However, while a growing number of companies are trying to integrate sustainable and green factor into their supply chains, many companies still limit themselves in extending sustainability throughout the chain. This situation is comprehensible due

to the incompatibility between the search for improving efficiency in supply chains and the promotion of sustainable policies. These companies have failed due to not taking the business aspects into full account. To be more precise, logistics enterprises have failed in balancing the “planet” factor and “profit” factor in terms of eco-design in which the keyword “eco” stands for both economy and ecology.

4.1 Eco-value

The classical approach to gaining sustainability and competitiveness in the food packaging supply chain is to design green packaging by reducing the eco-burden of the packaging. In this study, the EVR method was chosen for evaluating the eco-burden with the value provided by the packaging.

EVR method presented by Svanes, Vold, Møller, Pettersen, Larsen and Hanssen in 2010 is used to study the combined systems of packaging and the packaged products across the whole distribution chain from manufacturer to end consumer and the life cycle from raw material extraction to the waste phase. This methodology proposes a holistic approach incorporating both the eco-burden as well as the functionality based on five main categories including environmental sustainability, distribution cost, product protection, market acceptance and user-friendliness. According to Svanes and colleagues (2010, 161-175), this methodology allows quantitative comparisons across the design process between different package solutions and offers a full description of the properties of the packaging solution. It is irrefutable that this method covers all aspects across the entire supply chain not solely at the point of purchase. Hence, packaging designers can use this method as a toolbox to achieve the balance of environmental impact versus value creation.

4.1.1 The essence of eco-cost in strategic competitive throughout the food packaging supply chain

The eco-cost of a product plays a vital role in achieving competitive advantage in the supply chain. From a business strategy perspective, it is a double-edged sword that brings both benefits and drawbacks to pro-active strategies. However, it is irrefutable that having low eco-costs will contribute significantly to providing a product with a competitive edge in the future especially when “green products” or “green packaging” have been a topic on the daily agenda. The “green” value that consumers can perceive from the product that they have purchased is not an external cost anymore. On the contrary, enterprises should consider it as an internal cost inside the pillar of the true cost. (See Figure 16)

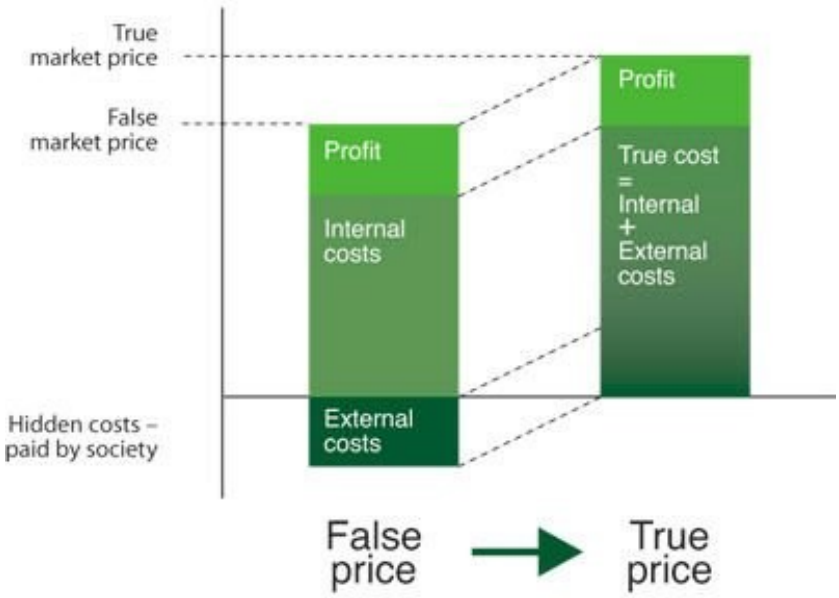

Figure 16. Eco-cost as an internal cost inside true market price. (Adapted from Econation for people and planet 2020)

According to Weaver and Vogtländer (2012, 229-248), the product portfolio matrix below demonstrates the link between eco-costs and the value-costs ratio that can

help packaging enterprises determine the right way to concentrate throughout the entire supply chain. (See Figure 19)

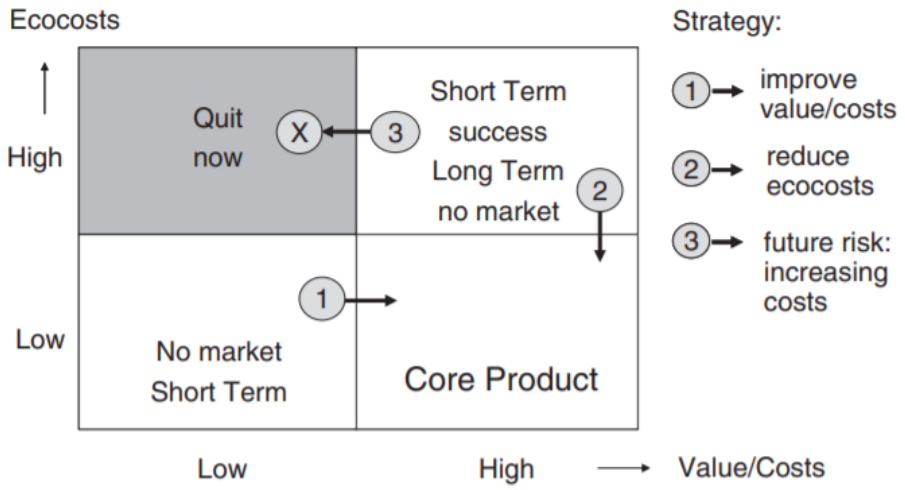

Figure 17. Product portfolio matrix for the innovation strategy of a company. (Adapted from Wever and Vogtländer 2012, 229-248)

It is easy to realize from the product portfolio matrix above that the product comes with a combination of a high value-costs ratio and low eco-costs. This will become dominant in the market soon due to a high competitive edge. Precisely, the critical explanation for the high price is that packaging enterprises need money to cover the potential production cost of green products and that the higher price can prevent the "rebound effect" that was described by economists Daniel Khazzoom and Leonard Brookes in the 1980s. It is important to note that a higher price is only accepted by the consumers when the perceived value is higher. Under the rebound effect from an environmental economic perspective, when the new energy-efficient technology was invented, it was automatic to think that this technology would help consumers to save energy as well as money in the long term. However, it brought an unwilling ret-roaction that energy efficiency may encourage a change in behavior towards in-

creased use. Instead of saving more energy, it turned out that the net energy consumption ended up being larger. Therefore, the higher price can prevent the “rebound effect”.

Those products that come with a high value-costs ratio and low eco-costs are a threat to decision making in business strategy. Such products will be eliminated from the market due to their high environmental impact and unsuitable fair price. None of the consumers wants to buy a product that costs much more than true value and causes environmental damage.

We also need to consider products that come with low eco-costs and a low value-costs ratio or products that come with high eco-costs and a high value-costs ratio. From a technical point of view, there will be not many markets for these products. If they do exist, the products will not last long due to temporary success at a particular time of need. There are plenty of opportunities for packaging enterprises to lower the eco-costs at an even higher value to meet and exceed the consumers’ expectation. Specifically, some of them could be:

- Rethinking of the whole production line or the entire supply chain. Sometimes, it is not all about packaging, because the process of production, as well as the supply chain activities can be the reason.
- A better choice of materials that can be recyclable or degradable to minimize the environmental impacts and support material recovery across the entire life cycle.
- Working with supply chain partners to minimize emissions or reduce unnecessary waste. An intelligent, vigorous and collaborative reverse logistics system for asset recovery is a typical example of this option.
- Influencing the buying behavior of the consumers by making products with low eco-costs more attractive

4.1.2 Is lowering eco-costs the only solution to achieve sustainability?

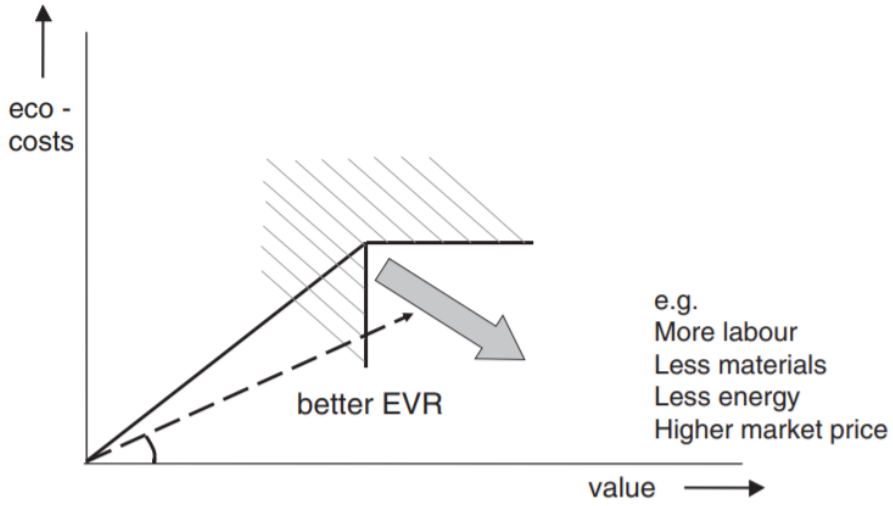

Figure 18. The double objective: lower eco-costs and higher value. (Adapted from Wever and Vogtländer 2012, 229-248)

It is universally acknowledged that the roads toward sustainability require a double objective in design and engineering which are lowering eco-costs and providing consumers with higher value at the same time. However, it is not always possible to increase value without increasing eco-costs. To give an illustration of what I meant, let's look at the case of the European automotive industry. Both BMW and Volkswagen focused on developing engines to achieve better fuel efficiency by combing lower CO2 emissions with higher acceleration characteristics. To be more precise, the value they offer consumers was emphasized much more frequent in their advertisement than the eco-costs. Nevertheless, consumers still believe to choose these brands to purchase cars. Therefore, adding value at low additional eco-costs is also possible to gain sustainability from the macro-economic point of view. In contrast, lowering eco-costs at the quality-costs is not a good choice for sustainability because it will affect the reputation of green products. Consumers cannot trust green products if the quality of them is worse than the original one.

4.2 Sustainable Packaging Logistics

4.2.1 Packaging and Sustainability

In this context, packaging appears as one of the critical keys that support the implementation of sustainable strategies in food packaging supply chains. Another key thing to remember, the packaging itself is a source of innovation in product packaging that creates major differences to gain competitive improvement in the market. Therefore, the packaging is not only about differentiating the product but it is also about all logistics activities carried out along the chain, that concentrate on reducing the overall negative impact on the environment and society in general.

According to Emas (2015), the concept of sustainability is formalized based on the long-term stability of the economic, environmental and social development. Furthermore, Elkington (1997) also defined the principles of sustainable design based on the results of a survey of international experts in corporate social responsibility (CSR) and sustainable development (SD) in terms of “triple bottom line” which is all about People, Planet and Profit.

For packaging, the “planet” side is all about the eco-system that should be concerned about especially from the aspect of the production and end-of-life phase. Reducing the eco-burden has been focused mainly in accordance with the planet’s perspective to achieve sustainable packaging. The profit side, where all stakeholders benefit including shareholders, costumers, employee and society, is also covered extensively. Finally, the people side or social component of sustainable packaging plays a vital role in this section especially coupled with the profit side. With the concept of sustainability, the people side and the profit side are not all about the fulfilment of the needs, they also go with the value of the product that consumers can perceive.

These 3 Ps can be extended to 5 Ps by including the packed product and the packaging since the packaging cannot be sustainable by itself without the combination of a certain product with a particular packaging. (See Figure 15).

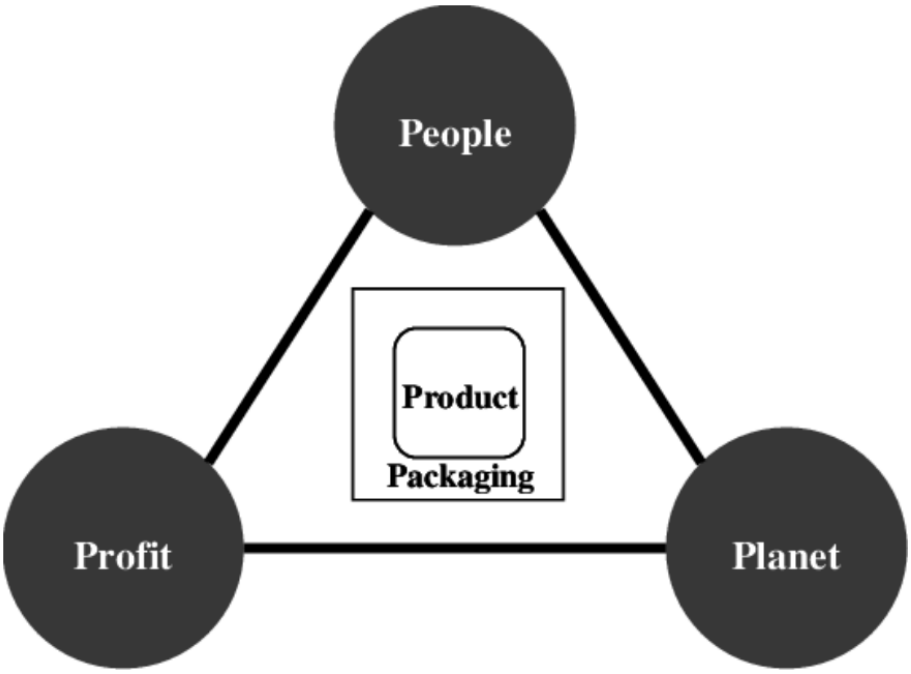

Figure 19.The five Ps of sustainable packaging: People, Planet, Profit, Packed product and Packaging. (Adapted from Curl and Diehl 2006, 21)

For this reason, adequate design of a package should make a contribution to the development of these dimensions of sustainability in supply chain. These dimensions will be described further in the following section as a preliminary step towards defining the concept of “Sustainable Packaging Logistics”.

4.2.2 Economic perspective

The role of packaging in the deployment of economic sustainability may not be aware properly because consumers do not place themselves in the position of packaging manufacturers, nor the packaging supply chain. Therefore, they do not appreci-

ate the true value contributed by packaging. From an economic perspective, packaging plays a vital role in both increasing sales and reducing costs throughout the supply chain. Indeed, the business historian Porter (1999) has observed that packaging occupies a unique position in the promotional sequence of consumption. Significantly, packaging plays a vital role in deciding the success or failure of a product in terms of successful business consisting of creating, packaging, advertising, distributing and selling products.

While e-commerce sales have increased dramatically in the EU over recent years, packaging expresses itself as an indispensable role in sale and marketing. To be more precise, packaging nowadays has been considered as a silent or invisible “salesperson” with tangible and intangible product characteristics, influencing ultimately the consumer purchase decisions (Rundh 2016, 2491-2511). Another key thing to remember is that green packaging has been a topic on the daily agenda of consumers so that packaging has a complete influence on the green image of the product.

Packaging also has an impact on the efficiency of the product at a logistics and productive level. To give an illustration of what I mean, let’s look at the case of returned products. Generally, returned products must be repacked and returned to the manufacturing point. For this reason, the economic and environmental performances of packaging have been affected due to several factors such as freight transport, energy consumption in buildings, unsold or damaged product and so on. Therefore, different dimensional approaches at the design stage should be considered precisely starting from the choice of material, choice of pack design, choice of the manufacturing process, choice of print method to the choice of the supply chain. By taking all these perspectives into account, the impact of packaging on the planet would be substantially minimized. Particularly, all unnecessary waste along the supply chain would be also eliminated in terms of the impact of the packaging system on logistics processes such as supplying, packing, handling, storing and transporting.

4.2.3 Environmental perspective

From an environmental perspective, the role of packaging in the development of environmental sustainability is reducing the environment impact or eco-burden of the packaging and using life cycle assessment to evaluate all types of packaging designs.

The Australian Sustainable Packaging Alliance has defined sustainable packaging in terms of environmental perspectives as follows. (See Table 3)

Table 3.Four principles used to define sustainable packaging in terms of environmental perspective. (Adapted from The Australian Sustainable Packaging Alliance 2020)

The role of packaging in the deployment of environmental sustainability	
Effective	-Fulfil the consumers' needs without compromising the ability of future generation -Fully functional requirement with minimal environmental and social impact
Efficient	-Optimize the usage of material and energy throughout the product life cycle
Cyclic	-Reduce reliance on virgin resources -Leverage existing material investments to produce new products
Safe	- No migration

In business reality, packaging design should be followed by specific legislation governed by the European Parliament and of the Council such as the regulation 94/62/EC on packaging and packaging waste.

4.2.4 Social perspective

While the economic and environmental dimensions of packaging sustainability have been examined and discussed in-depth, social development aspect has been not applied the same. Although the success of sustainable packaging development relies on both technological development and social considerations, many of the social aspects of sustainable packaging have not been taken into full account. In fact, they were often overlooked.

From a social perspective, packaging has often been understood as an intermediary helping consumers make a purchasing decision by supplying transparent, honest, understandable and truthful information. Besides, the packaging is also responsible for being a traditional market seller that communicates and advertises final products through words, colors and materials that form the proper shape of a package.

4.2.5 Impacts and gains of packaging

An overview of the impacts and gains of packaging related to the three components of sustainability can be seen in Figure 16 below.

Sustainability component	(Potential) impact / costs	(Potential) gains
Economic (profit)	– Purchasing of materials, energy. – Cost of processing, converting, printing, transportation, etc.	Improving market potential through: – Extended shelf life – Inducing sales through marketing – Convenience
Environmental (Planet)	– Impact of materials – Impact of processing, converting, printing, transportation, etc.	– Reducing wastage of food (Oki and Sasaki, 2000) – Reducing damage to products
Social (People)	– "*Fosters unsustainable consumption habits, such as not valuing materials and a 'throw-away mentality'.*" (Lewis, 2005)	– Enabling food availability in developing regions – Providing employment (Lewis, 2005) – Enabling life styles (e.g. single household portions) – Protecting children from harmful substances – Inducing proper wasting behavior

Figure 20. The impacts/costs and gains of packaging in relation to the three components of sustainability. (Adapted from Weaver and Templeman 2010)

4.3 Green packaging

It is irrefutable that phrases like "green packaging" and "sustainable packaging" get used so frequently in the discussion about the environmental responsible business that they have become a topic on the daily agenda. Although they are used interchangeably in the two words "green" and "sustainable", the meaning of them are indeed not the same. In this chapter, the author decided to conduct research on green packaging topic, the 4RID principles of green packaging and how green packaging plays in the sustainable supply chain.

4.3.1 The concept of green packaging

Green packaging as a term consists of two words “green” and “packaging”. In order to get the meaning of the concept more precisely, the author decided to clarify each word separately, thus to get a deeper imagination about the meaning.

All essential information related to packaging has been described explicitly in chapter 4 so that the keyword “green” will be focused to analyze in this section. “Green” is much more than a color. It is a typical symbol standing for our natural environment and the planet Earth.

It can be claimed that packaging is a heart of modern food industry in some ways, thus combining two words green packaging can be defined as sustainable packaging or eco-friendly packaging that uses biodegradable materials and energy-efficient manufacturing methods for the packaging of goods in order to make the lowest environmental impact and be harmless to human health. The core of green packaging is to protect the environment by using resources effectively and efficiently. In this regards, the author of this research shares the view that the environmental benefits of green products are not about having zero impact or fixing the environment, but rather that their eco-costs are less than those of similar products.

4.3.2 The 4R1D principles of green package

The concept “3R” and “1D” has already been applied in developed countries, which are Reduce, Reuse, Recycle and Degradable. However, during the intense situation of increasing global warming, consumers have asked for the demand of “4R1D” in packaging, which Reclaim is added on the principle of "3R1D”.

An overview of 3R principles including Reuse principle, Recycle principle and Reduce principle for achieving green packaging can be seen in Figure 17 and Figure 18 below.

Guiding principle and measures to achieve it	Explanation
Resource-efficient packaging	
Minimise materials	• Minimise packaging by: o eliminating unnecessary materials in packaging design o reducing the size, weight or thickness of packaging o optimising void space within the packaging design
Use recycled materials	• Maximise the use of recycled materials where it: o reduces the environmental footprint of the packaging (informed by life cycle analysis) o is not detrimental to the ability of the packaging to perform its primary function o is not detrimental to the product o does not violate health and safety standards
Minimise transport impacts	• Maximise the efficiency of transport through: o reducing the size, weight or thickness of packaging o fully utilising shipping space o using reusable packaging for distribution where appropriate
Maximise water and energy efficiency	• Energy and water consumption should be reduced by: o minimising the amount of material used for packaging o making production and distribution of the packaging and product more efficient o considering the use of renewable energy for the production of the packaging
Packaging made from low-impact materials	
Minimise risks associated with potentially toxic and hazardous materials	• Assess packaging for potentially toxic or hazardous substances that are likely to pose risk, and endeavour to reduce that risk
Use renewable and/or recyclable materials	• Renewable materials include paper, cardboard and biopolymers • Recyclable materials include paper, cardboard, some plastics and metals • Material selection should be based on a sound understanding of the whole-of-life impacts

Figure 21.Principles for achieving green packaging-Part 1. (Adapted from the Australian Packaging Covenant 2020)

Guiding principle and measures to achieve it	Explanation
Use materials from responsible suppliers	• Packaging materials should be purchased from companies that are committed to environmental sustainability and have a documented Environmental Management System
Recoverable packaging	
Design for reuse where appropriate	• Packaging can be designed to be reused for: o its original purpose e.g. return trips o another purpose e.g. packaging other items • Reuse should be considered where it is practical and environmentally beneficial
Design for recovery	• Maximise recovery and recycling at end of life by: o using recyclable materials o avoiding materials that may contaminate the recycling process e.g. materials bonded together, using more than one material in a package • Developing and implementing appropriate labelling on the packaging to encourage consumers to recycle or compost • Label packaging in accordance with labelling legislation to encourage consumers to recycle, compost or dispose of appropriately
Design for litter reduction	• Packaging that is consumed away from home (such as fast food and beverage packaging) has greater potential to be found in the litter stream. To reduce litter potential: o minimise the number of separate or easily separable components (e.g. screw cap lids, peel-off seals) o provide advice for consumers on the label to encourage appropriate disposal or recovery • Biodegradable or compostable materials that can break down in the environment could be considered for packaging that has greater potential to become litter. Environmental claims need to be verified and a whole-of-lifecycle approach adopted
Inform consumers about appropriate disposal	Consumers should be made aware of any environmental claims about recyclability or degradability so that they can dispose of packaging appropriately

Figure 22.Principles for achieving green packaging-Part 2. (Adapted from the Australian Packaging Covenant 2020)

Reclaim principle and Degradable are depicted in table 4 below.

Table 4.Reclaim principle and Degradeable principle for achieving green packaging. (Adapted from Quiang & Min 2015, 910-913)

Reclaim	• Usage of combustion packaging to access new energy sources, without creating secondary emissions. • Through the recycling of packaging waste, green products such as the use of thermal incineration, composting and other land quality improvement measures are developed for reuse.
Degradable	• Biodegradable packaging is an optimal solution for single-use packaging nowadays. • The degradable materials can be split, degraded and reduced in the natural environment by the impact of natural light or the micro-organisms in soil and water. Consequently, they can re-enter into the ecological environment and return to the nature in non-toxic ways (Quiang & Min 2015).

4.3.3 The circular economy

The packaging is often considered as a short-lived product due to its intended role in the product system. Furthermore, the packaging is rarely considered by the manufacturer, retailer, brand owner due to its short life span. Both manufacturers and consumers usually consider packaging as a single-use product, thus enterprises nowadays do not realize the vital role of packaging in a circular economy business model especially cost savings.

It is universally acknowledged that economic growth must be decoupled from resource consumption. Otherwise, our planet's resources will soon run out. For this reason, Katherine O'Dea illustrated a circular economy business model in which new values can be found new uses of materials. (See Figure 23)

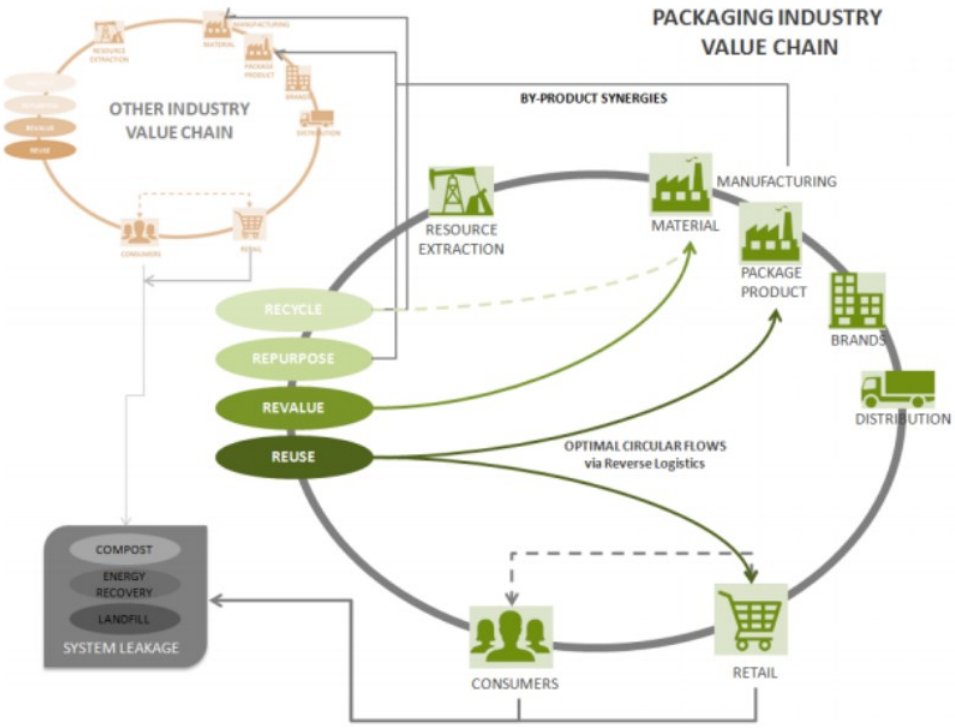

Figure 23. A more circular packaging value chain. (Adapted from O'Dea 2015)

4.3.4 Reverse logistics system

It is irrefutable that green logistics has been the primary tool for enterprises to make their businesses environmentally sustainable. However, reverse logistics also plays a vital role in improving environmental sustainability. Eventually, there are many triggers make the firms have to take reverse logistics into full account. For instance, the increase of landfill costs, new environmental regulations, pressure from consumers and laws. In this chapter, the author would like to introduce the essence of the reverse logistics activities that affect the circular packaging value chain in terms of eco-packaging.

According to Rogers and Tibben-Lembke (1998), reverse logistics is the process of planning, implementing, monitoring and controlling the efficient and cost-effective flow of raw materials, in-progress inventory, finished goods and related information

from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal. Basically, reverse logistics deals with returned products and unsold products. In addition, reusing containers, recycling packaging materials, re-manufacturing and refurbished activities can also be related to the concept of reverse logistics.

Typical reverse logistics consist of diverse activities including collection, sorting/separation, recycling, reprocessing, reuse, redistribution and disposal of used, damaged, discarded or obsolete good, as well as packaging and shipping materials from the end user. An overview of a common reverse flow that all these actions are directed to decrease the amount of waste, reduce the environmental impacts and improve the state of the environment at the same time, is depicted in Figure 24.

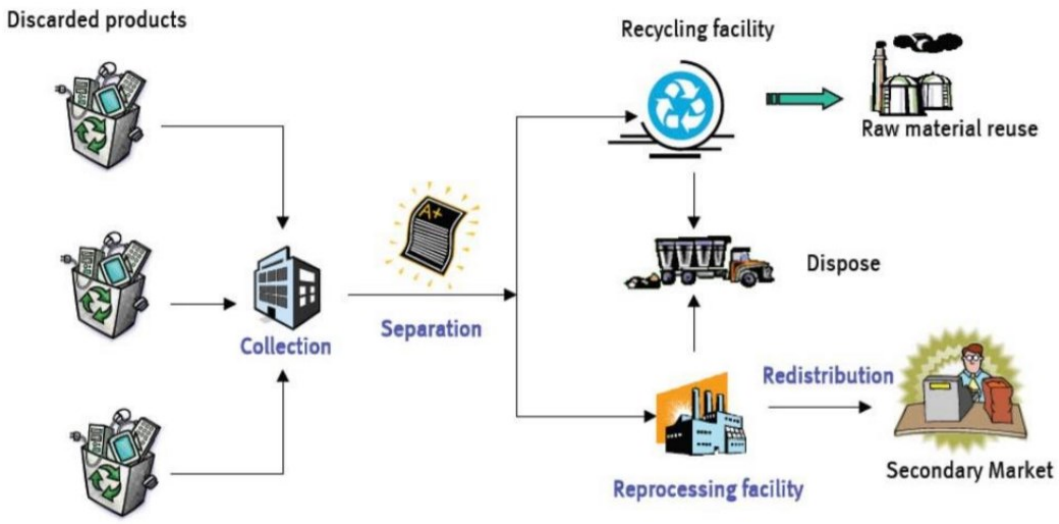

Figure 24. Reverse flow. (Adapted from Bajor 2014)

5 The comparison of sustainability of five different packages

In this chapter, the materials were collected from the article, which is all about eco-efficient value creation, was written by Wever and Vogtländer in 2012 in terms of economic and environmental perspective. The objective of this comparison is to answer the first research question in chapter 2.1.2.

According to Wever and Vogtländer (2012, 229-248), five-example packages were chosen from the same retail, from the same brand, in the same amount and at the same time so that the authors can limit the potential variables may happen and the only two variables for each pair of packages can happen such as the packaging design and the retail price.

Each pair of different materials was purchased only once not including discount price so that the reliability of the result can be guaranteed. General information of five pairs of materials is given in Table 5.

Table 5. Five pairs of food packaging. (Adapted from Wever and Vogtländer 2012, 229-248)

Examples	Type of packaging design	Information
Tomato Ketchup Volume: 300ml	Glass bottle	• 197.1g glass • 3.19g steel cap • Retail price: €1.22
	Squeezable plastic bottle	• 22.69g PET • 3.88g PP • Retail price: €1.35
Sport bottled water Volume: 500ml	The one has regular cap	• 15.33g PET • 2.03g cap • Retail price: €0.36
	The one has sport cap	• 15.33g PET • 4.1g cap • Retail price: €0.61

Mustard Volume: 215g	Basic mustard jar	• Weight: 145.1g • 5.93g steel lid • Retail price: €1.47
	Luxury table jar	• Weight: 202.9g class • 4.72g PE lid • Retail price: €1.77
Italian herbs Volume: 12g	Glass jar with a plastic lid	• 85.9g glass • 6.49g PP lid • Retail price: €1.39
	Re-closable flexible plastic pouch	• 3.11g LDPE • Retail price: €1.25
Chocolate drink Volume: 1L	Tetra Brick	• 29.94g carton • 3.56g PP • 0.069g aluminium foil • Retail price: €1.17
	Multipack of 4 cans	• 11.69g aluminium foil • 3.99g carton • 1.82 LDPE • Retail price: €3.1

The realistic pictures of these samples are depicted in Figure 25 below.

Figure 25.Five pairs of food packaging. (Adapted from Wever and Vogtländer 2012, 229-248)

The analyses of these food packaging have been performed in terms of two single indicators which are carbon footprint (kg CO2e) and eco-costs (euro). The calculation was performed by the Idemat app which helps consumers be able to make a fast track LCA and a final decision during purchasing in terms of sustainable materials selection. (See Figure 26)

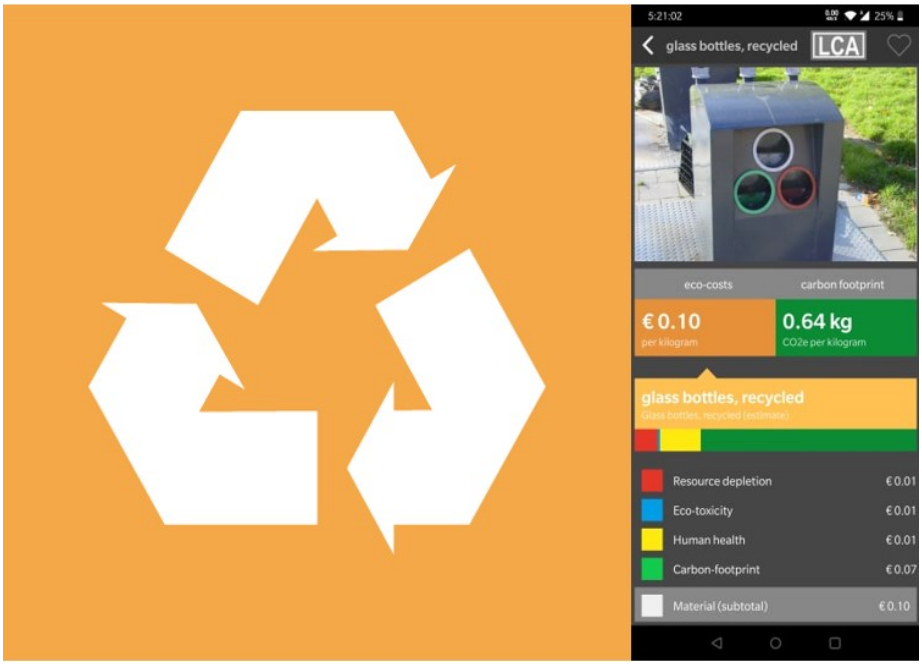

Figure 26.Idemat app. (Adapted from Idemat app 2020)

5.1 Tomato ketchup

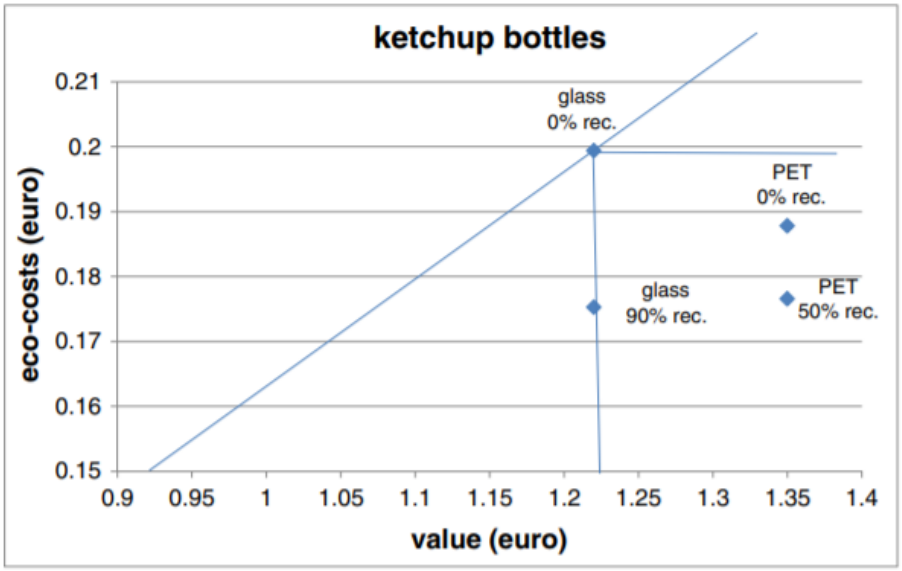

Figure 27.The value and the eco-costs of a 300 ml tomato ketchup in a glass or PET bottle. (Adapted from Wever and Vogtländer 2012, 229-248)

It is easy to notice that the value of the PET bottle is higher than the glass bottle due to high convenience in real life. Furthermore, it is irrefutable that the eco-costs of the PET bottle with zero percentage of recyclability is also much lower because of lightweight. However, the price of the recycled glass is lower than the price of the recycled because of the differences between the technology and the recycling system in each country. In this case, it is apparent that plastic or recyclable plastic will be the first choice in choosing tomato ketchup bottles.

5.2 Water bottles

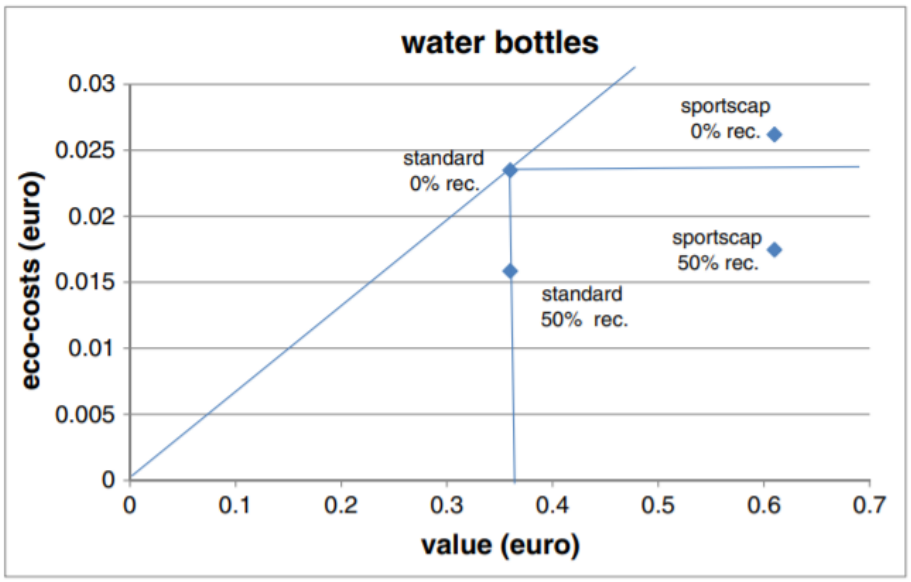

Figure 28.The value and the eco-costs of 50 cc water, standard or with sports cap. (Adapted from Wever and Vogtländer 2012, 229-248)

It is apparent that the water bottle with sport cap is a typical example of unsustainable packaging due to the significant increase in eco-costs and values. Moreover, even if the designers replace normal plastic with recyclable plastic, the results still remain the same. However, from an optimistic perspective, the angle created between the

recyclable regular water bottle and the recyclable water bottle is quite significant so that the designers or the enterprise should improve the product in both green and sustainable way. In this case, the first choice interval of water bottles is hard to identify because it depends too much on specific circumstances, for instance, sports events and daily life uses. However, from my point of view, standard water bottles would be the most preferred products of all consumers due to lower eco-costs and environmental impacts as well.

5.3 Mustard

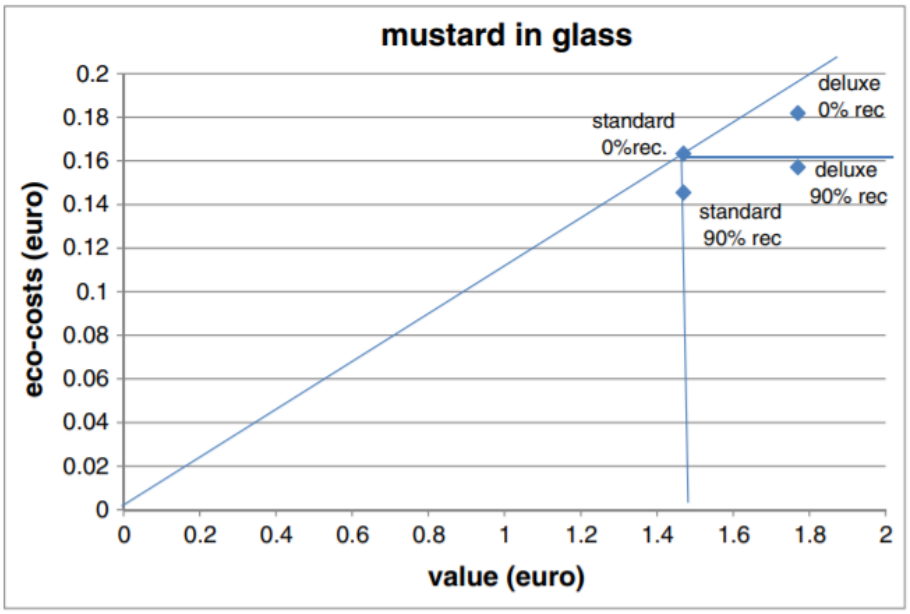

Figure 29.The value and the eco-costs of 215 g mustard jar, standard and 'deluxe'. (Adapted from Wever and Vogtländer 2012, 229-248)

Figure 30 shows that the deluxe jar is not an example of eco-efficient value creation. To be more precise, consumers can easily realize that this product not only makes the environmental impact more than the standard one but the value it offers consumer is not worth. Moreover, no matter the material can be replaced by the recy-

cled material up to 90%, it is still not the most optimal solution since the angle created between the standard one and the recyclable one is considerably small. In this case, it is apparent that the standard mustard bottles would be the most preferred goods in purchasing mustard products because the deluxe bottles not only caused more damages to environmental but also offered customers low value based on consumers' evaluation of the quality or desirability of a product compared to its peers.

5.4 Herbs

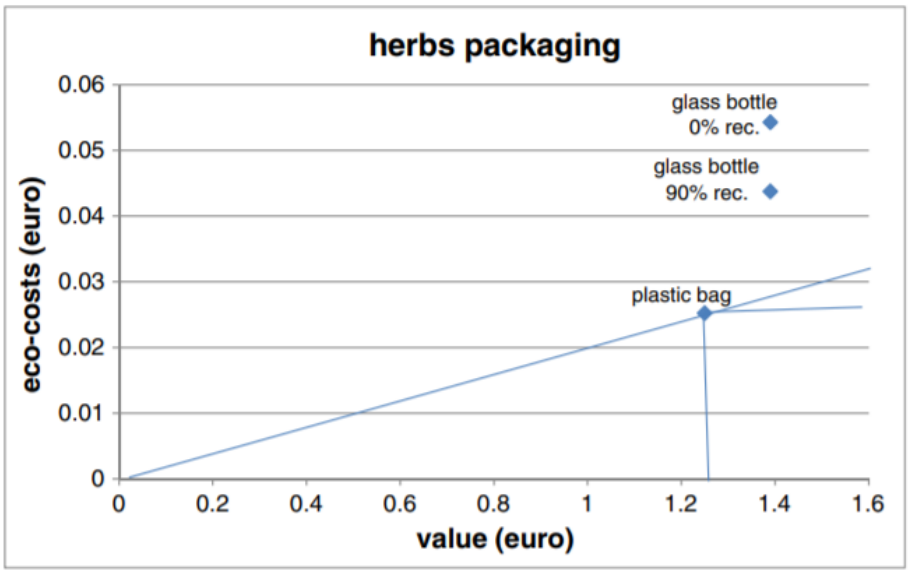

Figure 30.The value and the eco-costs of 12 g herbs in a plastic bag or a glass jar. (Adapted from Wever and Vogtländer 2012, 229-248)

It is hardly surprising that the EVR of glass bottle is much higher than the EVR of plastic bag since the added value of glass bottle requires more materials that incidentally increases the eco-costs. According to Wever and Vogtländer (2012, 229-248), transportation during the entire supply chain has been assumed due to the fact that Italian herbs were sold in the Netherlands so that the statistics performed by Figure 32

is not totally accurate. However, it shows the food packaging enterprises that efficiency and sustainability may not be incompatible. In this case, the herbs plastic package would be the first choice due to low eco-costs compared to its peers.

5.5 Chocolate milk

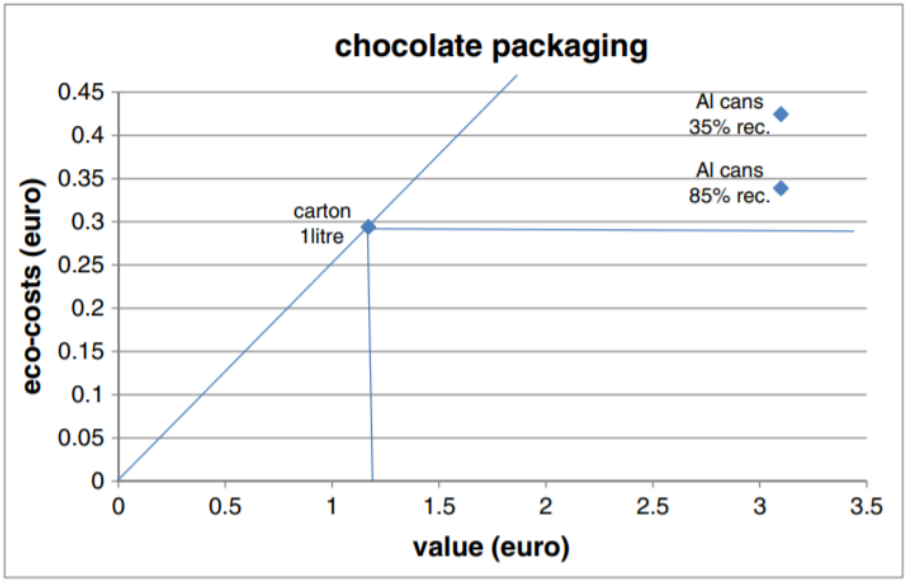

Figure 31.The value and the eco-costs of I l water, in carton or in four cans. (Adapted from Wever and Vogtländer 2012, 229-248)

The significant gap of eco-costs between carton material and aluminium material in Figure 34 somehow explains why consumers prefer purchasing aluminium cans to buying the 1-liter carton can. No matter the value is much higher, consumers still choose to use it because they perceived the added value more than the price they had to pay. Furthermore, it is more convenient and handy for consumers to consume aluminium can than consumer a big 1-liter carton can. This aluminium product is a typical example of green packaging that successful can adopt a sustainable supply chain in terms of environmental, economic and social development. In this case, the first choice interval of chocolate milk is hard to identify because it depends too much on typical circumstances, for instance, outdoor activities and daily life uses. However,

from my point of view, aluminium cans would be the most preferred products of all consumers compared to its peers.

6 Analysis of green packaging in consumer product choices

6.1 The online survey

First of all, an online survey was created to understand and analyze how consumers concern about green packaging during global warming in terms of social, economic and environmental perspective. Secondly, the author wants to study the self-awareness of consumers in separating different recyclables in their daily life. Thirdly, the author also wants to study both tangible and intangible values consumers can perceive from green packages. Finally, the survey was created to answer the second question and the third question in chapter 2.1.2.

The online survey is about the analysis of green packaging in consumer product choices. Google Docs was chosen to make an online survey by the author because it is free, no manual saves, easily accessible anywhere, highly compatible with all devices and suitable with any professionals.

6.2 Results Analysis

How old are you?	Sum of Number
17-20	8.94%
21-25	41.05%
26-30	19.26%
31-35	10.65%
36-40	6.08%
Others:	14.03%
Grand Total	**100.00%**

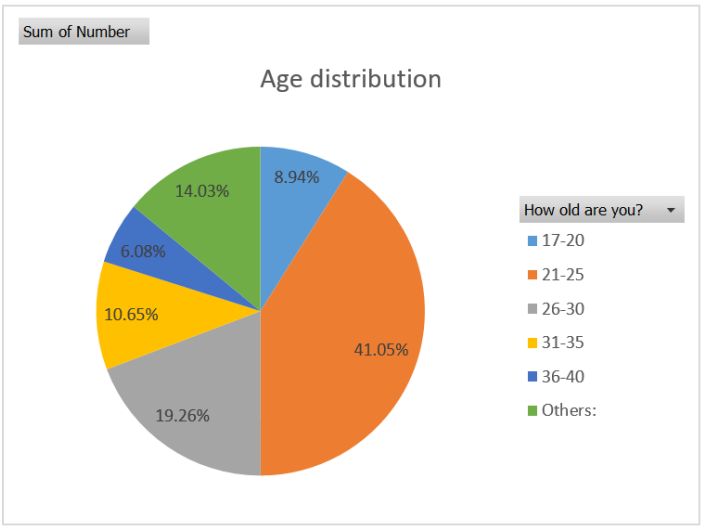

Figure 32.Age distribution

Over 200 people aged from 17 to over 40 years old joined the survey to help the author collect data and analyze them from different perspectives so that the reliability and validity of this study are guaranteed. Figure 32 shows that the responsibility of protecting our environment does not only belongs to the median ages but also the younger generation and the older generation. It is surprising that the young generation soon shows their concern in environment protection and accounts for nearly 10% of all respondents in the survey. It can be also claimed that the parents or family must play an active role in inculcating their children with good habits and teaching them to become more responsible for the protection of the environment and natural resources by wise daily usage of natural resources such as electricity, water and other resources. Moreover, young people nowadays do realize that if they do not take action at present, they will live with the consequences of current environmental decisions and regret the vanished youth for doing nothing. What's more, future generations will also be affected by these decisions.

Figure 33.Green Packaging Survey.

It is hardly surprising that more than 70% of consumers aware of their responsibilities in separating their waste during intensive global warming. Moreover, in accordance with Figure 33, it is a positive sign for packaging manufacturers when more than 70% of consumers are willing to sacrifice for sustainable packaging in terms of pricing, performance, and convenience. This miracle happed because consumers realize that if they do not help and support the packaging manufacturers, these firms will not have enough financial to survive. For this reason, consumers are cognizant of their roles in helping the packaging manufacturers which also means they are helping themselves, their future generation and their current environment as well. Therefore, this win-win situation is the best solution for everyone who is involved.

It is easy to notice that there are a small number of consumers do not sort their packaging waste no matter they are conscious of the label and marking attached with food packaging. This undesirable situation happened since logistics companies have been focusing too much on green logistics but forgot the essential role of reverse logistics. As mentioned above in chapter 4.3.4, reverse logistics is responsible

for planning, implementing, monitoring and controlling the efficient and cost-effective flow of raw materials, in-progress inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal. Therefore, the packaging firms must recognize the essence of reverse logistics system because the environmental sustainability cannot be gained without it.

However, consumers are also at least partially to be responsible for that. To be more precise, consumers do not realize that the only way to reduce the overall environmental impact is the strong collaboration between consumers and manufacturers. Relying too much on the responsibility of one side makes consumers create themselves a subjective evaluation of their responsibilities.

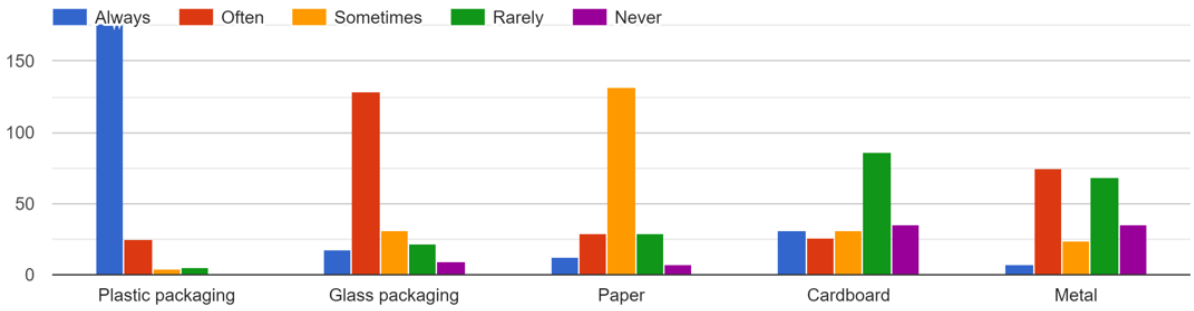

Figure 34.Analysis of consumer buying behavior on different materials.

It is surprising that plastic packaging products are dominating the market. It is irrefutable that the benefit of plastic products are so enormous that we can barely deny it. High durability, cost-effective, high flexibility and easy to transport and store are the typical reasons which explain the high popularity of plastic products.

Figure 34 implies that consumers do not have so many choices in purchasing eco-friendly products compared to their peers. For this reason, it can be claimed that those green packages, that are qualified for 4R1D principle, are not so popular in the

market nowadays. Moreover, there are considerably a large number of green products that offer consumers values which are not worth enough based on consumers' evaluation of the quality or desirability factor compared to its peers. For this reason, the packaging manufacturers should consider again carefully the perceived value that consumers can see and gain through purchasing their products.

In accordance with Figure 34, no matter consumers are very concerned about the environmental issues, they are still struggling to turn this into their practical purchases in real life. Another factor contributes to the fact why other materials are not the first choice compared to plastics materials is that being green needs time in customers' lives that are not available in growing significantly busy lifestyles. It is universally acknowledged that most convenience products are made from plastic materials. For this reason, paper, glass, metal or other materials cannot become the most preferred products of all consumers.

According to Moisander (2007, 404), such day by day decisions on realistic environmental or ethical solutions often lead to interconnections and result in a 'motivational and practical complexity of green consumption'. Each purchase has consequences for ethic, resource, waste and society. Therefore, the most effective way to influence consumers purchase decision is to make sustainable behavior the default option. For example, plastic project without plastic bag was set in Kerava city located in Finland. When "Plastic Bagless Kerava" was set as the default option to reduce the usage of plastic, all individuals living in the city will have no choice but using reusable bags based on wood fiber. As a result, the total environmental impact will be reduced.

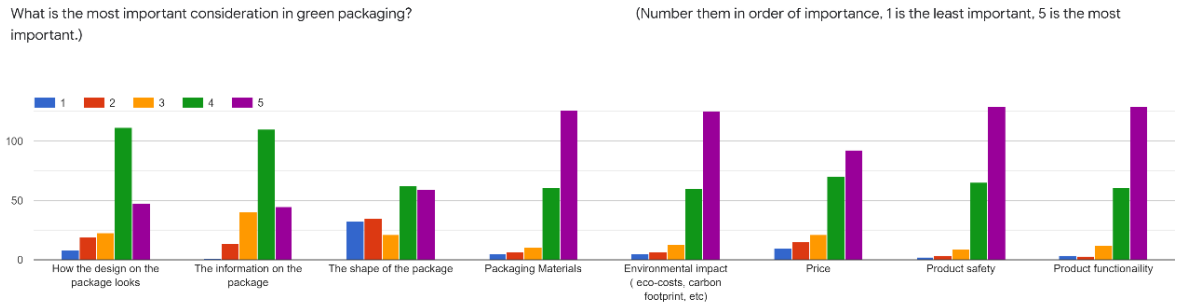

Figure 35.Analysis of consumer buying behavior on packaging.

Figure 35 shows that the most common criteria that consumers always consider when they are deciding to purchase green products are packaging materials, environmental impact, product safety, product functionality and price. The design, the information and the shape of green products are the second thoughts that need to be considered before making a decision.

It can be claimed that consumers are aware of the positive and adverse environmental effects of the products they purchase. Figure 35, in fact, shows that more than 50% of respondents evaluated packaging materials and environmental impacts as the most important factors for them to make a decision about whether or not to purchase a product.

Figure 36. Analysis of the first 5 criteria consumers consider before purchasing green products.

It can be claimed that the perceived quality of green products had a positive influence on consumer buying behavior. Brand knowledge of product used to be the top factor that influences on consumers' purchasing intention. However, the Earth is gradually warming up and climate change has changed from something only specialist atmosphere experts would be concerned about, into a topic on the daily agenda for politicians and economists, as this issue taps into every individual's life. For this reason, green or eco-friendly product has become the top priority for consumers to consider to adopt sustainable lifestyles.

Besides considering the packaging materials and the environmental impacts, consumers also compare the price they have to pay with the perceived value they can obtain through some criteria such as product functionality and product safety. It is irrefutable that no matter what kind of material that the product was made from,

the safety factor is always the top priority needs to be considered and guaranteed to protect consumers and the packaging manufacturers themselves as well. In this case, the product functionality criteria are totally not about the tangible performance of the function that consumers can see but it is also about the recyclable option or the second-hand availability of the product.

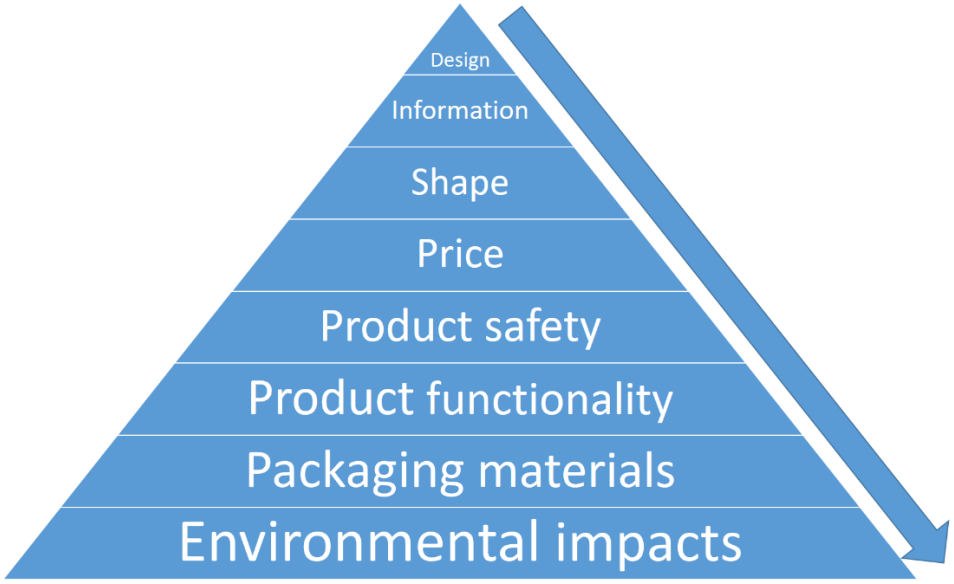

Figure 37. The green criteria hierarchy.

It can be claimed from Figure 37 that consumers appeared to consider as higher quality when the green goods are under a well-known brand name. Although green has been the factor which has an impact on consumer purchase behavior nowadays, brand still plays an indispensable role during the decision-making process. In this survey, brand knowledge was believed to be the bottom-down approach and perceived quality acted as the top-up approach.

7 Conclusions

The main objective of this research was to answer the question: **How does green packaging relate to sustainability in supply chain?** It can be claimed that the efficiency of adopting green packaging and sustainability in supply chain are compatible. In this context, the author proved the statement by providing the irrefutable benefits of adopting green packaging in terms of environmental, economic and social development. Moreover, the author also pointed out the essence of choosing materials for packaging design at the design stage by comparing five different pairs of food packaging Furthermore, reduction in carbon footprint and lower eco-costs are apparently the key values that green packaging can contribute to gain sustainable supply chain in terms of environmental, economic and social development.

At the same time, from my point of view, packaging design complied with this EVR model can create value through differentiation to dominate the FMCG business. Different characteristics of packaging are the key used to enhance the market performance of many products to gain sustainability and marketing. This EVR model indeed provides enterprises and consumers with a way to access which differentiation efforts make sense from a sustainability perspective.

This study advances our knowledge on the topic by examining consumers' purchasing behavior on green products. In particular, in accordance with the survey, sources of environmental information play a vital role in helping consumers understand green consumption of the products they purchased because the only way to increase the consumption of green products is the availability and clarity of trusted information. Moreover, the outcome retrieved from the survey offer support for this notion in that the author found that consumers who see and understand the environmental impacts of those green products they purchased are more likely to increase their total green consumption. Besides, consumers are willing to pay more because they know they made the right choice for their lives as well as their environment. Furthermore, it seems that consumers appear to pay more attention to green marketing

messages. To be more precise, in accordance with the survey, more than 70% of consumers consider packaging materials and the production processes which produce truly green products.

These findings have essential implications to public and enterprises in that a growing number of consumers are showing their interest in understanding how to choose right products nowadays that can help them reduce their overall environmental impacts compared to the old times. The results indicate a strong relationship between consumers who are looking for eco-friendly products and enterprises that are searching for the way to gain sustainability during this intense situation. These finding retrieved from the survey suggest the essence of providing information to consumers about the environmental impacts of those products appeared in the market nowadays. Additionally, the survey showed that enterprises should concentrate on providing accurate environmental information to gain trust from consumers and they will never fail the efforts the packaging enterprises have made. Instead, consumers will try their best to support those enterprises that are willing to change to gain sustainability in supply chain through green packaging.

It is surprising from the results of the survey that the personal knowledge about environmental matters is related to sustainability in supply chain. In particular, the more environmental matters consumers are conscious about, the more green consumption enterprises will get. Those consumers who are aware of personal risk regarding the environment are willing to buy more green products to mitigate it. For this reason, these findings point to the essence of environmental education. If we want to see a widespread change in changing our environment, consumers must have decent knowledge of environmental problems and how these problems are mitigated. The survey further suggests that enterprises would be more successful at undertaking these education efforts. Beside enterprises, both government and parent should be included to increase consumer knowledge and reduce the overall environmental impacts.

Green packaging plays a vital role in reducing environmental impact nowadays. Therefore, companies must aware of the essence of adopting green packaging in order to benefit the environment and themselves. To be more precise, green packaging is not all bout gaining sustainability in the supply chain but it also reminds human being about the fact that resources on Earth are limited.

8 Discussion

Reducing eco-costs without decreasing in value to gain sustainability and competitiveness in supply chain is one of the most challenging issues that food packaging enterprises are dealing with. If this solution happens, consumers have to accept that the product will have a lower physical functionality or a lower intangible functionality. To give an illustration of what I meant, let's look at the analysis of the water bottles in chapter 6.2. As mentioned above, the water bottle with the sport cap is not sustainable due to higher eco-costs and higher value no matter it provides the additional convenience from physical functionality's perspective. Ignoring the convenient value the sport cap offers consumers, the standard water bottle is certainly a preferable design choice. Therefore, from my point of view, instead of creating new designs of the water bottle, the drink company should focus on supporting material recovery across the entire life cycle. If increased production of recycled plastic generates an equal decrease in primary plastic production, total environmental impact is reduced.

Reducing eco-burden of the packaging comes with the increase in value is the trendy solution food packaging enterprises are aiming to. Plastic tomato ketchup is a typical example of this trend. With the increase in value, the packaging enterprises can cover the potential production cost of green products and the higher price can prevent the "rebound effect". However, the packaging firms should be cautious that the price of the product is too high compared with the perceived values consumers can get, it will counteract.

It is universally acknowledged that eco-packaging will reduce environmental impacts. However, this is not completely true since the collaboration between consumers and manufacturers is the key factor decides the environmental impacts. However, there is a loose connection between consumers and packaging manufacturers that the packaging manufacturers only focused on designing green and sustainable packaging but forgot totally to build an intelligent, vigorous and collaborative reverse logistics system for asset recovery. For this reason, a possible solution that should be taken into full account is implementing smart codes such as QR codes on the packaging to help consumers access more data not only about goods but also about the nearest location of collection point so that the overall environmental impact can be reduced effectively and efficiently.

There is a general consensus that most food packaging designs only show the Möbius Loop symbol with the plastic resin codes, that makes consumers doubt if these green packages are true or not. Therefore, the food packaging manufacturers should consider replacing the plastic resin codes with a percentage figure so that the connection between consumers and packaging manufacturers can be tighter and more resilient.

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Appendices

Appendix 1. Online survey questions.

Green Packaging

*The survey takes up 2 minutes to complete.

*The objective of this survey is to understand how consumers concern about green packaging during global warming in terms of social, economic and environmental perspective.
*The survey includes general information about you and some brief questions about the link between green packaging, consumers and packaging manufacturers.
*The information provided in the survey will be anonymous and will be used as part of a thesis. Therefore, feel free to express your opinions.

Let's start!!!
*Required

Respondent Background Information

1. How old are you? *

Mark only one oval.

- ◯ 17-20
- ◯ 21-25
- ◯ 26-30
- ◯ 31-35
- ◯ 36-40
- ◯ Others:

2. What is your gender? * *

Mark only one oval.

- ◯ Female
- ◯ Male
- ◯ Prefer not to say

3. What is your profession? *

Mark only one oval.

- Student
- Job seeker
- Office worker
- Elder
- Other:

Green Packaging

4. Are you familiar with the label and marking in the food package below? *

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Maybe

5. How often do you buy a product that is packaged in different materials? *

Mark only one oval per row.

	Always	Often	Sometimes	Rarely	Never
Plastic packaging	◯	◯	◯	◯	◯
Glass packaging	◯	◯	◯	◯	◯
Paper	◯	◯	◯	◯	◯
Cardboard	◯	◯	◯	◯	◯
Metal	◯	◯	◯	◯	◯

6. Do you know how to separate your "Recyclables" properly? *

Mark only one oval.

◯ Yes
◯ No
◯ Maybe

7. Do you sort your packaging waste every day if it is recyclable? *

Mark only one oval.

◯ Yes
◯ No
◯ Maybe

8. Do you know what can be sorted or what should not be sorted into plastic packaging waste? *

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Maybe

9. Do you know how to find the nearest Rinki Eco Take-back point? For example: Searching on the map via website https://www.kierratys.info/ *

Mark only one oval.

- ◯ Yes
- ◯ No

10. What is the most important consideration in green packaging? (Number them in order of importance, 1 is the least important, 5 is the most important.) *

Mark only one oval per row.

	1	2	3	4	5
How the design on the package looks	◯	◯	◯	◯	◯
The information on the package	◯	◯	◯	◯	◯
The shape of the package	◯	◯	◯	◯	◯
Packaging Materials	◯	◯	◯	◯	◯
Environmental impact (eco-costs, carbon footprint, etc)	◯	◯	◯	◯	◯
Price	◯	◯	◯	◯	◯
Product safety	◯	◯	◯	◯	◯
Product functionaility	◯	◯	◯	◯	◯

11. Are you willing to sacrifice for the notion of sustainable packaging in terms of pricing, performance, and convenience? *

Mark only one oval.

◯ Yes
◯ No
◯ Maybe

Appendix 2. Summary of the calculations on packed tomato ketchup.

(Adapted from Wever and Vogtländer 2012, 229-248)

Weight		Materials type, primary production and processing	Eco-costs (€/kg)	CO_2 equivalent (kg CO_2/kg)	Eco-costs (€/bottle)	CO_2 equivalent (kg CO_2/bottle)
300 ml tomato ketchup in glass + closure, 0% recycled						
197.1 g	Glass	Idemat2010 Glass bottles	0.207	0.888	0.04090	0.17504
3.19 g	Steel	Idemat2010 Steel (market mix average)	0.494	1.609	0.00157	0.00513
		Idemat2010 Rolling steel	0.029	0.051	0.00009	0.00016
		Total			0.04256	0.18034
300 ml tomato ketchup in PET + closure, 0% recycled						
22.69 g	PET	Idemat2010 PET bottle grade	1.070	2.893	0.02428	0.06563
		Idemat2010 Blow moulding bottles	0.213	1.088	0.00482	0.02468
3.88 g	PP	Idemat2010 PP	1.028	1.973	0.00399	0.00766
		Idemat2010 Injection moulding	0.257	1.333	0.00100	0.00517
		Total			0.03409	0.10314
300 ml tomato ketchup in glass + closure, 90% recycled glass						
19.71 g	Glass	Idemat2010 Glass bottles	0.207	0.888	0.00409	0.01750
177.39 g	Glass	Idemat2010 Glass from recycled bottles	0.071	0.373	0.01265	0.06618
3.19 g	Steel	Idemat2010 Steel (market mix average)	0.494	1.609	0.00157	0.00513
		Idemat2010 Rolling steel	0.029	0.051	0.00009	0.00016
		Total			0.01841	0.08898
300 ml tomato ketchup in PET + closure, 50% recycled						
11.345 g	PET	Idemat2010 PET bottle grade	1.070	2.893	0.01214	0.03282
11.345 g	PET	Idemat2010 PET, recycled (estimate)	0.212	1.081	0.00241	0.01226
		Idemat2010 Blow moulding bottles	0.213	1.088	0.00482	0.02468
1.94 g	PP	Idemat2010 PP	1.028	1.973	0.00199	0.00383
1.94 g	PP	Idemat2010 PP, recycled	0.240	1.240	0.00047	0.00241
		Idemat2010 Injection moulding	0.257	1.333	0.00100	0.00517
		Total			0.02283	0.08116
Contents and transport						
300 ml tomato ketchup glass, contents and transport						
300 g	Tomato	Idemat2010 Tomato, standard	0.493	3.30	0.14783	0.99017
500 g	500 km	Idemat2010 Truck + trailer 24 tons net (ton·km)	0.036 €/ton·km	0.095 CO_2/ton·km	0.00901	0.02387
		Total			0.15684	1.01403
300 ml tomato ketchup PET, contents and transport						
300 g	Tomato	Idemat2010 Tomato, standard	0.493	3.30	0.14783	0.99017
327 ton·km	500 km	Idemat2010 Truck + trailer 24 tons net (ton·km)	0.036 €/ton·km	0.095 CO_2/ton·km	0.00589	0.01561
		Total			0.15372	1.00578

Summary table

Tomato ketchup	Eco-costs (€)	Price (€)	Relative value	Relative eco-costs
300 ml tomato ketchup in glass + closure, 0% recycled	0.199	1.22	1	1
300 ml tomato ketchup in PET + closure, 0% recycled	0.188	1.35	1.11	0.94
300 ml tomato ketchup in glass + closure, 90% recycled glass	0.175	1.22	1	0.88
300 ml tomato ketchup in PET + closure, 50% recycled	0.177	1.35	1.11	0.89

Appendix 3. Summary of the calculations on the water bottles. (Adapted from Wever and Vogtländer 2012, 229-248)

Weight		Materials type, primary production and processing	Eco-costs (€/kg)	CO_2 equivalent (kg CO_2/kg)	Eco-costs (€/bottle)	CO_2 equivalent (kg CO_2/bottle)
50 cl water bottle, standard, 0% recycled						
15.33 g	PET	Idemat2010 PET bottle grade	1.070	2.893	0.01641	0.04434
		Idemat2010 Blow moulding bottles	0.213	1.088	0.00326	0.01667
2.03 g	PP	Idemat2010 PP	1.028	1.973	0.00209	0.00401
		Idemat2010 Injection moulding	0.257	1.333	0.00052	0.00271
		Total			0.02227	0.06773
50 cl water bottle, sports cap, 0% recycled						
15.33 g	PET	Idemat2010 PET bottle grade	1.070	2.893	0.01641	0.04434
		Idemat2010 Blow moulding bottles	0.213	1.088	0.00326	0.01667
4.1 g	PP	Idemat2010 PP	1.028	1.973	0.00421	0.00809
		Idemat2010 Injection moulding	0.257	1.333	0.00105	0.00547
		Total			0.02493	0.07457
50 cl water bottle, standard, 50% recycled						
7.67 g	PET	Idemat2010 PET bottle grade	1.070	2.893	0.00820	0.02217
7.67 g	PET	Idemat2010 PET, recycled	0.212	1.081	0.00163	0.00828
		Idemat2010 Blow moulding bottles	0.213	1.088	0.00326	0.01667
1.02 g	PP	Idemat2010 PP	1.028	1.973	0.00104	0.00200
1.02 g	PP	Idemat2010 PP, recycled (estimate)	0.240	1.240	0.00024	0.00126
		Idemat2010 Injection moulding	0.257	1.333	0.00026	0.00135
		Total			0.01463	0.05174
50 cl water bottle, sports cap, 50% recycled						
7.67 g	PET	Idemat2010 PET bottle grade	1.070	2.893	0.00820	0.02217
7.67 g	PET	Idemat2010 PET, recycled	0.212	1.081	0.00163	0.00828
		Idemat2010 Blow moulding bottles	0.213	1.088	0.00326	0.01667
2.05 g	PP	Idemat2010 PP	1.028	1.973	0.00211	0.00404
2.05 g	PP	Idemat2010 PP, recycled	0.240	1.240	0.00049	0.00254
		Idemat2010 Injection moulding	0.257	1.333	0.00053	0.00273
		Total			0.01621	0.05645
50 cl water bottle, standard, contents and transport						
50 g	Water	Negligible	0	0	0.00000	0.00000
67 g	500 km	Idemat2010 Truck + trailer 24 tons net (ton·km)	0.036 €/ton·km	0.095 CO_2/ton·km	0.00121	0.00320
		Total			0.00121	0.00320
50 cl water bottle, sports cap, contents and transport						
50 g	Water	Negligible	0	0	0.00000	0.00000
69 g	500 km	Idemat2010 Truck + trailer 24 tons net (ton·km)	0.036 €/ton·km	0.095 CO_2/ton·km	0.00124	0.00329
		Total			0.00124	0.00329

Summary table

Water	Eco-costs (€)	Price (€)	Relative value	Relative eco-costs
50 cl water bottle, standard, 0% recycled	0.023	0.36	1	1
50 cl water bottle, sports cap, 0% recycled	0.026	0.61	1.69	1.11
50 cl water bottle, standard, 50% recycled	0.016	0.36	1	0.67
50 cl water bottle, sports cap, 50% recycled	0.017	0.61	1.69	0.74

Appendix 4. Summary of the calculations on packed mustard. (Adapted from Wever and Vogtländer 2012, 229-248)

Weight		Materials type, primary production and processing	Eco-costs (€/kg)	CO_2 equivalent (kg CO_2/kg)	Eco-costs (€/container)	CO_2 equivalent (kg CO_2/container)
215 g mustard in glass + closure, 0% recycled glass						
145.1 g	Glass	Idemat2010 Glass bottles	0.207	0.888	0.03011	0.12886
5.93 g	Steel	Idemat2010 Steel (market mix average)	0.494	1.609	0.00293	0.00954
		Idemat2010 Rolling steel	0.029	0.051	0.00017	0.00030
		Total			0.03321	0.13871
215 g mustard in glass + closure 'deluxe', 0% recycled glass						
202.9 g	Glass	Idemat2010 Glass bottles	0.207	0.888	0.04210	0.18019
4.72 g	PE	Idemat2010 PE (LDPE)	1.058	2.098	0.00499	0.00990
		Idemat2010 Injection moulding	0.257	1.333	0.00121	0.00629
0.91 g	Liner	Idemat2010 Al trade mix (65% prim 35% sec)	2.748	8.434	0.00250	0.00767
		Total			0.05081	0.20406
215 g mustard in glass + closure, 90% recycled glass						
14.51 g	Glass	Idemat2010 Glass bottles	0.207	0.888	0.00301	0.01289
130.59 g	Glass	Idemat2010 Glass from recycled bottles	0.071	0.373	0.00931	0.04872
5.93 g	Steel	Idemat2010 Steel (market mix average)	0.494	1.609	0.00293	0.00954
		Idemat2010 Rolling steel	0.029	0.051	0.00017	0.00030
		Total			0.01543	0.07145
215 g mustard in glass + closure 'deluxe', 90% recycled glass						
20.29 g	Glass	Idemat2010 Glass bottles	0.207	0.888	0.00421	0.01802
182.61 g	Glass	Idemat2010 Glass from recycled bottles	0.071	0.373	0.01302	0.06813
4.72 g	PE	Idemat2010 PE (LDPE)	1.058	2.098	0.00499	0.00990
		Idemat2010 Injection moulding	0.257	1.333	0.00121	0.00629
0.91 g	Liner	Idemat2010 Al trade mix (65% prim 35% sec)	2.748	8.434	0.00250	0.00767
		Total			0.02594	0.11002
215 g mustard in glass + closure, contents and transport						
72 g	Mustard seeds	Idemat2010 Clover seed, from farm	1.7126	6.85	0.12331	0.49339
143 g	Vinegar	Negligible	0	0		
366 g	500 km	Idemat2010 Truck + trailer 24 tons net (ton·km)	0.036 €/ton·km	0.095 CO_2/ton·km	0.00659	0.01747
		Total			0.12990	0.51086
215 g mustard in glass + closure 'deluxe', contents and transport						
72 g	Mustard seeds	Idemat2010 Clover seed, from farm	1.7126	6.85	0.12331	0.49339
143 g	Vinegar	Negligible	0	0		
423 g	500 km	Idemat2010 Truck + trailer 24 tons net (ton·km)	0.036 €/ton·km	0.095 CO_2/ton·km	0.00762	0.02019
		Total			0.13093	0.51358

Summary table

Mustard	Eco-costs (€)	Price (€)	Relative value	Relative eco-costs
215 g mustard in glass + closure, 0% recycled glass	0.163	1.47	1	1
215 g mustard in glass + closure 'deluxe', 0% recycled glass	0.182	1.77	1.20	1.11
215 g mustard in glass + closure, 90% recycled glass	0.145	1.47	1	0.89
215 g mustard in glass + closure 'deluxe', 90% recycled glass	0.157	1.77	1.20	0.96

Appendix 5. Summary of the calculations on packed Italian herbs.

(Adapted from Wever and Vogtländer 2012, 229-248)

Weight		Materials type, primary production and processing	Eco-costs (€/kg)	CO_2 equivalent (kg CO_2/kg)	Eco-costs (€/container)	CO_2 equivalent (kg CO_2/container)
12 g herbs in plastic bag, 0% recycled						
3.11 g	PE (?)	Idemat2010 PE (HDPE)	1.026	1.929	0.00319	0.00600
		Idemat2010 Extrusion	0.115	0.422	0.00036	0.00131
		Total			0.00355	0.00731
12 g herbs in glass + closure, 0% recycled						
85.9 g	Glass	Idemat2010 Glass bottles	0.207	0.888	0.01782	0.07629
6.49 g	PP	Idemat2010 PP	1.028	1.973	0.00667	0.01280
		Idemat2010 Injection moulding	0.257	1.333	0.00167	0.00865
		Total			0.02616	0.09774
12 g herbs in glass + closure, 90% recycled						
8.59 g	Glass	Idemat2010 Glass bottles	0.207	0.888	0.00178	0.00763
77.31 g	Glass	Idemat2010 Glass from recycled bottles	0.071	0.373	0.00551	0.02884
6.49 g	PP	Idemat2010 PP	1.028	1.973	0.00667	0.01280
		Idemat2010 Injection moulding	0.257	1.333	0.00167	0.00865
		Total			0.01563	0.05793
12 g herbs in plastic bag, contents and transport						
12 g	Herbs	Idemat2010 Clover seed, from farm	1.7126	6.85	0.02055	0.08223
15 g	2000 km	Idemat2010 Truck + trailer 24 tons net (ton·km)	0.036 €/ton·km	0.095 CO_2/ton·km	0.00108	0.00286
		Total			0.02163	0.08510
12 g herbs in glass + closure, contents and transport						
12 g	Herbs	Idemat2010 Clover seed, from farm	1.7126	6.85	0.02055	0.08223
104.4 g	2000 km	Idemat2010 Truck + trailer 24 tons net (ton·km)	0.036 €/ton·km	0.095 CO_2/ton·km	0.00752	0.01993
		Total			0.02807	0.10216

Summary table

Herbs	Eco-costs (€)	Price (€)	Relative value	Relative eco-costs
12 g herbs in plastic bag, 0% recycled	0.0252	1.25	1	1
12 g herbs in glass + closure, 0% recycled	0.0542	1.39	1.11	2.15
12 g herbs in glass + closure, 90% recycled	0.0437	1.39	1.11	1.74

Appendix 6. Summary of the calculations on packed chocolate milk.

(Adapted from Wever and Vogtländer 2012, 229-248)

Weight		Materials type, primary production and processing	Eco-costs (€/kg)	CO_2 equivalent (kg CO_2/kg)	Eco-costs (€/container)	CO_2 equivalent (kg CO_2/container)
1000 ml chocolate milk in carton, 0% recycled						
29.94 g	Carton	Idemat2010 Board	0.178	0.985	0.00534	0.02950
3.56 g	PP	Idemat2010 PP	1.028	1.973	0.00366	0.00702
		Idemat2010 Injection moulding	0.257	1.333	0.00092	0.00475
		Total			0.00992	0.04127
4 × 250 ml four-pack chocolate milk in Al containers, 35% recycled						
30.394 g	Aluminium	Idemat2010 Aluminium (primary)	4.028	12.232	0.12242	0.37179
16.366 g	Aluminium	Idemat2010 Aluminium (secondary)	0.373	1.379	0.00610	0.02256
		Idemat2010 Forging aluminium	0.042	0.238	0.00198	0.01111
3.99 g	Carton	Idemat2010 Board	0.178	0.985	0.00071	0.00393
1.82 g	PE	Idemat2010 PE (LDPE)	1.058	2.098	0.00192	0.00382
		Idemat2010 Extrusion	0.115	0.422	0.00021	0.00077
		Total			0.13334	0.41398
4 × 250 ml four-pack chocolate milk in Al containers, 85% recycled						
7.014 g	Aluminium	Idemat2010 Aluminium (primary)	4.028	12.232	0.02825	0.08580
39.746 g	Aluminium	Idemat2010 Aluminium (secondary)	0.373	1.379	0.01482	0.05480
		Idemat2010 Forging aluminium	0.042	0.238	0.00198	0.01111
3.99 g	Carton	Idemat2010 Board	0.178	0.985	0.00071	0.00393
1.82 g	PE	Idemat2010 PE (LDPE)	1.058	2.098	0.00192	0.00382
		Idemat2010 Extrusion	0.115	0.422	0.00021	0.00077
		Total			0.04789	0.16022
1000 ml chocolate milk in carton, contents and transport						
1000 g	Milk	Idemat2010 low-fat milk from dairy, no quotas	0.2644	0.60	0.26445	0.60000
1070 g	500 km	Idemat2010 Truck + trailer 24 tons net (ton·km)	0.036 €/ton·km	0.095 CO_2/ton·km	0.01928	0.05107
		Total			0.28372	0.65107
4 × 250 ml four-pack chocolate milk in Al containers, contents and transport						
1000 g	Milk	Idemat2010 Mini milk, from dairy, no quotas	0.272	1.168	0.27205	1.16817
<50 g	Ingredients	Negligible				
1033 g	500 km	Idemat2010 Truck + trailer 24 tons net (ton·km)	0.036 €/ton·km	0.095 CO_2/ton·km	0.01861	0.04931
		Total			0.29066	1.21748

Summary table

Chocolate milk	Eco-costs (€)	Price (€)	Relative value	Relative eco-costs
1000 ml chocolate milk in carton, 0% recycled	0.294	1.17	1	1
4 × 250 ml four-pack chocolate milk in Al containers, 35% recycled	0.424	3.1	2.65	1.44
4 × 250 ml four-pack chocolate milk in Al containers, 85% recycled	0.339	3.1	2.65	1.15