Lappeenranta University of Technology
LUT School of Energy Systems
LUT Mechanical Engineering

Oyajumo Seyi Emmanuel

CONICAL ALUMINUM CAN

Examiners: Professor Henry Lindell
Professor Juha Varis

Lappeenranta University of Technology
School of Energy Systems
Department of Mechanical Engineering

Oyajumo Seyi

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Examiners: Professor Henry Lindell
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ABSTRACT

Keywords: Packaging, beverages can, sustainability design, Aluminum can, and conical can

The current beverage (cylindrical shape) cans are stacked on each other after production, thus consuming a lot of space. Indirectly, this could result to high carbon emission during transportation. The problem is how to minimize the carbon emission based on different contradicting viewpoints. It was suggested that a conical shape of "the beverage can" could be a solution for the space optimization of empty beverage can transportation, thus creating the title for this research "Conical aluminum can". They would be stacked inside each other before filling and after usage. This was based on design for sustainability and the consumer perspective and willingness toward sustainability. However, it was noticed that the industry is unwilling to incorporate this change.

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Great is God’s faithfulness unto me, I found it as a privilege to complete a master´s degree in Mechanical Engineering, it is not by strength nor by might but for His grace, therefore I return all glory to Him

16th January 2015, Lappeenranta, Finland

Seyi Emmanuel Oyajumo

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LIST OF ABBREVIATIONS

EMEA	Europe, the Middle East and Africa
IUCN	The International Union for Conservation of Nature
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
USA	United States of America
WWF	World Wide Fund for Nature
SPI	Society of the Plastics Industry

1 INTRODUCTION

More than 300 million Aluminum cans are produced in a day and over 100 billion in a year in the United States of America alone (Duncan & Hosford, 1994, p. 48). The beverage cans are mostly transported by road while the rail and sea transportation are used for long distance shipment. In Europe, the environmental issue related to the transportation is being given a major attention; this could be noticed by the various policies being made. The three priorities of the Europe 2020 vision, which was the European Union commission vision for the social market economy for the 21st century, are smart growth, sustainable growth and inclusive growth. To achieve the vision, one of the targets is the "20/20/20" climate and energy target. The "20/20/20" means twenty percent (20%) reduction in the greenhouse gases by the year 2020 when compared to year 1990 data, twenty percent improvement in the energy efficiency by the year 2020 and that by the year 2020, the renewable energy should have twenty percent (20%) of the total energy production. (EUROPEAN COMMISSION, 2010.) Considering the European Commission vision, the drive to low-carbon economy is necessary for sustainable growth. Thus, the improvement in logistics system as well as its optimization is a necessity (SPC Finland's, 2012, p. 4-7). Another focus of the European Commission is the target of 60% carbon dioxide (CO_2) reduction by the year 2050 in comparison to the year 1990 data (SPC Finland's, 2012, p. 7).

Over the years, the manufacturers of beverage have exercised similar precision and accuracy that were used for making the metallic part of an airplane wing and the same analytic method used in developing the space vehicle in the design of the cans toward perfection. As a result of this, the weight of the beverage can have reduced over the years. (Duncan & Hosford, 1994, p. 48.) Still, more research is needed in exploring further, the application of the principle of sustainability on the beverage can. Sustainability is important in today's world, the world is faced with the challenge of limited resources and the growing population is a pressure on the limited resources. Therefore, the environmental impact of the beverage can lifecycle would be an important study to consider. Research has shown that packages contribute tremendously to environmental pollution and that cans' packages contribute to food and product waste reduction, thereby reducing the environmental impact of this loss (Williams & Fredrik, 2011. p. 43-48).

According to PE Americas (2010) on the environmental footprint of 1000 cans, it will produce 121.6 kg of carbon dioxide, 47 g of carbon monoxide, 240 g of Nitrogen oxides, 436 g of sulphur dioxide and 209 g of volatile organic compounds. However, these values might be reduced through researches. The purpose of this thesis is to consider the beverage can in relations to sustainability principle, method and tools. It is hoped that a new design of the beverage can could be suggested. This design is expected to contribute to making the beverage can a more sustainable product as well as supporting the European Union vision 2020. It is believed that this study would be beneficial to the beverage producer, the aluminum manufacturers, the prospective customer, environment decision makers, as well as the general public. It is hoped that this study will contribute to the packaging design trend of aluminum can and it would further raise debate about the necessity of the reduction of carbon emission during the aluminum cans shipment. (PE Americas, 2010.)

According to Kuusipalo (2008, p. 330), one of the main factors in packaging design should be the environmental factor. The environmental effect of product as well as the material are the factors which should have been considered during the packaging material selection and designing. A responsible manufacturing strategy could be the usage of material that could be recycled, reused or recovered through an efficient energy recovery system (Kirwan, 2005). According to Kirwan (2005, p. 160) the interest of government, commercial factors, consumer and consumer groups has made the environmental issue of packaging visible. The consumer and consumer groups are environmentally conscious in the environmental credential of goods and services. The governments in Western Europe and North America have banned certain packages and also set the recycling rate (Seppänen, 2013) and the commercial factors are rising in meeting the government and consumer interest. All these make the research about sustainable package a critical matter.

1.1 Problem definition

The current research on beverage can has mostly been toward reducing the thickness, less has been considered in the area of space optimization of the product after production. The current beverage cans are stacked on each other after production, thus consuming a lot of space. Indirectly, this could result to carbon emission during transportation (Jawahir, Badurdeen & Rouch, 2013, p.6). The problem is how to minimize the carbon emission based on different contradicting viewpoints, such as empty beverage can shipment. Also alternative shapes of the beverage can would be an important area of research as it raised a question that ‘could the current design be more sustainable and better optimized?’

Furthermore, the transportation sector is a major player in the supply chain, goods and service delivery relies mostly on it. Also, it is a major contributor to the economic development. However, transport has become one of the major challenges of the 21st century (EcoTransIt World*,* 2011, p. 4). It is the source of more than a quarter of the worldwide CO_2-emissions. Also, it has the largest possibility to grow than any other sector. Thus, an adequate management is necessary. The table 1 shows the mode of transportation in relation to the propulsion energy for beverage can shipment.

Table 1.Transport modes, vehicle and propulsion system (EcoTransIt World, 2011, p. 8).

Transport mode	Vehicle	Propulsion energy
Road	Single truck, truck trailer	Diesel fuel
Rail	Trains	Electricity and diesel fuel
Sea	Ocean going sea ship	Heavy fuel oil, marine diesel oil, marine gas oil

Also, the rate of energy consumption of the freight transport is directly proportional to the rate of the emission. Emission is due to the use of combustion engines. Some of the parameters that affect the rate of energy consumption are the vehicle type, the capacity utilization, the traffic route, the driving conditions, the cargo specifications, and the total weight of the freight and transport distance (SPC Finland's 2012, p. 6-7).

The transport emissions from the fuel are the carbon dioxide (CO_2), nitrogen oxide (NO_x), sulphur oxide (SO_x), non-methane hydrocarbon (NMHC), carbon monoxide (CO) and the particle matter (EcoTransIt World*,* 2011, p. 6; Ban-Weiss *et al.* 2008, p. 220-222). The effect of the emission could be noticed in the climate change and the medical cases (Lloyd & Cackette, 2001, p. 809-811)., thereby making the impact of the transport on the mental and physical to be receiving attention from the stakeholder (Cavoli et al., 2014). Climate change is the major shift in the statistics of the weather; it refers as major changes in temperature and rainfall etc (Alhorr, Eliskandarani&Elsarrag, 2014). The climate change could result to rising temperatures, shifting of the rainfall pattern and increase in the global mean sea level. Table 2 itemizes the effect of each compound of the emission. (SPC Finland's, 2012, p. 6; Alhorr, et al, 2014.)

Table 2. Emission effect (Adapted from PE Americas, 2010; Kagawa, 2002, p. 349; Morgan, Reger & Tucker, 1997, p. 643-656*).*

Compound	**Effect.**
CO_2	Climate change
Nitrogen Oxide	Eutrophication
Sulphur oxide	Acidification
Particular matter	Cardiovascular disease

1.2 Research Question

Providing solution to the research problem, there is a need for scientific and practical investigation. Why is beverage can a sustainable product? What could be done to reduce the carbon emission during its transportation? What could be the stakeholders' perception to the 'conical shape structure of the beverage can? Why will 'the conical can' be considered a sustainable product?

1.3 Literature Review

The current beverage can is a result of over 80 years of research, development and improvement. Morean (2009) gives details about the history of the beverage can. He stated that at the initial stage, the beverage can faced challenges. The product and process simulation on the aluminum beverage can was done by Takeuchi (1994, p. 178-188). The parameters and the effect of the manufacturing process were researched by Folle, Silveira & Schaeffer (2008, p. 347-352). Almost a decade ago, the researches about the beverage can has been focused on the sustainability aspect. Liew (2005, p. 80-81) suggested about using single alloy instead of the current two alloys for the aluminum can manufacturing. Further details about the various studies, research on package, the beverage can and sustainability is explained in the section below.

1.3.1 Sustainability in Packaging industry

The packaging is an important factor in product development. It is an integral system in the overall chain: starting from production, to supply chain and final consumption. Since the 1960s and 1970s, various research related to sustainability have been done in the packaging industry, these were due to various legislation and pressure calling for reduction of the environmental impacts of its products (Lewis, 2005, p 45-46). Packaging has been defined in many industries based on its functions, characteristics and perspective. Some of definitions relate to the functionality and utility. The package is considered to offer protection, preservation and communication features to the product. Also, it is seen as a product that adds value to the main product; it keeps the product clean and makes the product marketable.

However, for the consumer, the packaging is something viewed as an unnecessary part of a product which has an extra cost to the consumer. And many considers it as an environmental menace where as in the developing countries, 30-50% of food produced is wasted due to lack of packaging, warehousing and transportation (Kuusipalo, 2008, p. 330). The negative perception about packaging by the consumer can be traced to the fact that by the time the packaging reaches the consumer, it sometimes has completed its intended function, thus it is considered a waste of resource or waste burden to the environment. Another factor can be the unawareness of the function of packaging in fullness.

In another view, the packaging can be viewed as the safe transport medium for the product from the production, through the supply chain with the aim of protecting the product from damages; it helps to store food over a long period and prevent waste (Williams & Wikström, 2011, p. 47-48). Also, it can be summarized as a secondary product, providing safety, quality and economical feature for its primary product. With the global trend factors; people and future market, this means an increase in population, changes in wealth and health status. Thus leading to rise in consumption, increase in demand, urban growth, increase in pollution among others. The packaging is considered a part of the solution for controlling the pollution and consumption (Halloran *et al.* 2014, p. 294).

However, government, non-governmental organization (NGOs), academics, competitors, business and professional association's etc. have strong concerns about the impact of the packaging on the environment, most especially, the effect of large quantity and different materials for the manufacturing of a "single use" product (Lewis, 2005, p 45-55). This is considered as major environmental challenge. And to address the challenge, the solution could be an increase in "sustainability" and more specifically, for sustainable consumption. It is viewed that the route of sustainable consumption will create sustainability in packaging. Thus a greater responsibility is on the industry in considering life cycle analysis of their products, starting from the design, through all, the whole stages of the product (Grönman *et al.* 2013, p 197-198). However, the consumer interest is an important factor in the final implementation of the sustainable consumption; they determine the trend in the industry.

The term sustainability encompasses a complex range of ideas. The word "sustainability" originates from the Latin word "*sustinere*" (to hold; *tenere*, up; *sus*). Many scholars and organization have various definitions for it. The environment is one of eight Millennium Development Goals intended for measuring improvements in people's lives and comparing the country's economy. And the overall theme of the environment is “Ensure Environmental Sustainability” (United Nations Development Group, 2010, p. 4). Invariably, the common future in environmental issue lies in the political and economic framework. Sustainability thinking has been based on three cores area. They are the environment, the economic and the social sectors. These core areas are interrelated and could be dependent on each other (Jawahir et al., 2006, p. 1).

According to the United Nation (1987), sustainability development is defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. Basically, the definition is centered on the concept of needs, that not only should we be considerate of the future but we should be mindful of the present. Various organizations such as IUCN, UNEP and WWF define sustainability as the method or process of improving the quality of human life within the varying capacity of the earth resources and eco-systems (World Wide Fund for Nature, 1993). Basically, common to all the sustainability definition and meanings is the purpose of minimizing human being effects on the environment. Many critics have considered the packaging, most especially packaging of polymer material as waste and/or problem that its existence should be stopped by legislation. The campaign against polymer can ascertain to it (Srinivasan & Wen, 2014, p. 395-397). Also, the beverage can is not excluded in this campaign associating packages as a waste product or environment pollutant.

Sustainable consumption is considered as a measure of drafting the consumption in line with sustainability. The most used definition of sustainable consumption is of the 1994 Oslo Symposium. According to the Norwegian Ministry of the Environment (1994), the sustainable consumption is “the use of services and related products which respond to basic needs and bring a better quality of life while minimizing the use of natural resources and toxic materials as well as emissions of waste and pollutants over the life cycle of the service or product so as not to jeopardize the needs of future generations” (Halloran *et al.* 2014, p. 294; Norwegian Ministry of the Environment, 1994).

The Packaging impact on the environment is visible throughout its entire life cycle (Seppänen, 2013, p. 23). Starting from the production stage of the beverage can to various usage stages, waste and pollution are generated. The waste could have ended if it was used for something else. The sustainable position of Aluminum could be that it should not be a polluter or/and a pollution generator during the production, transportation, usage and disposal. Furthermore, it should not be a drain directly or indirectly on irreplaceable product. It is extremely important that “the aluminum can” could deliver the desired demand set for it as a packaging product and present packaging in a method which will minimize the environmental impact associated to manufacturing, transportation, usage and disposal.

1.3.2 Design for sustainability of the beverage can

Nowadays, the idea of design for sustainability is a growing part of product design discussions. Design for sustainability (D4S) is a globally recognized method used in the industries for the product in compliance with the sustainability guideline “to be more sustainable”. The companies have used this principle for improving profit margins, environmental performance, product quality, market opportunities and social benefits. Some of the techniques used in D4S are usage of recycling material, toxic waste reduction, product life extension and designing for recyclability system etc. (Jawahir et al., 2006, p.1-5), Considering what an ideal sustainable product design methodology would be, it is assumed by Jawahir, Badurdeen & Rouch (2013, p. 9-15) to be the product that conforms to the element of design for sustainability. Thus, the ideal design will not compromise any of the elements of sustainability. The figure 1 shows the element that should guide in designing an ideal sustainable product.

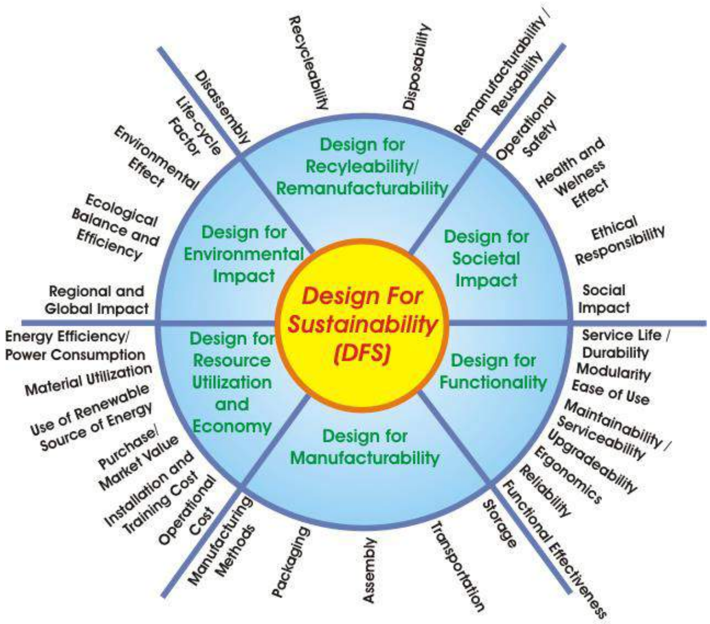

Figure 1. Basic elements and sub-elements of product design for sustainability (Jawahir et al., 2006, p. 5).

A new sustainable product ought to be a pure engineering innovation that improves its environment, society value with little or no changes in the system (Jawahir, Badurdeen & Rouch 2013, p. 9-11). Most of the design methodologies are geared in overcoming the deficiency of the current design and manufacturing processes. Also, some might be to improve the conformity of the product to the sustainability goals. The result of a new design might lead to a reduction in the amount of material, energy and production costs as well as improving manufacturability and functionality of the product. Also design for sustainability should consider the life cycle of the product; the product should be designed such that the base material will keep flowing even after the recycle stage (Jawahir, et al., 2013, p. 9-11).

1.3.3 The beer can history

Prior to the packaging of beer in the cans, the kegs and bottles was being used for beer package. Also, beer are sold directly from the tap. In USA, interest about packaging beer in cans started after 1920. Already, metal can have been used for other foods. The American can companies started the idea of packaging beer in cans (Morean, 2009). Although, challenges arose in its technicality and marketability. One of the engineering challenges was the type of metal to be used and how to manufacture the can which can withstand the internal pressure resulting from beer pasteurization. The consumer notion that metal taste could be tasted in the beer was another issue before the canning of beer (William & Duncan, 1994, p. 48; Morean, 2009). Nevertheless the American can company was able to solve those problems by the introduction of its “Keglined cans”. The can has the mechanical properties necessary to withstand the pressure during pasteurization. Also, it has an internal lining which serves as a barrier between the beer and the metal (Morean, 2009).

The first can produced was from the heavy gauge steel. It had a flat top and the opening was done by using the punching tool. Figure 2 shows the first set of beer cans and the market approach the can used by the American can company to address the anticipated consumer concern about the metallic taste in the beer. In the United States, the Gotfried Krueger brewing company of Newark, New Jersey was the first brewery to start packaging beer in cans. In 1933, a temporary canning line was installed and 2000 cans of Krueger’s special beer can was produced, which was the first beer to be sold in can. It was filled with 3.2% beer. This was the beginning of the beer can. The result of the survey done by the company was highly encouraging. Sooner, two new can beers were introduced by the company (William & Duncan, 1994, p. 48; Morean, 2009).

Figure 2. On the left the first set of beer cans and on the right the early beer can (credit: Morean, 2009).

Sooner; the Krueger can beer were dominating the market from the three major national players (Anheuser-Bush, Pabst, and Schlitz) (Morean, 2009). In July, 1935, the Pabst joined the can beer trend; they exported beer in flat tops can. The Schlitz introduced a new can design; their larger beer was packed in right can in figure 2 (Cone top) (Morean, 2009). When the other breweries saw the success rate and acceptability of the beer can, they started packaging beer in cans. In 1941 alone, over a billion cans were sold, although it was just about 10% of the packaged beer market share. However, by 1960, the canned beer sales had surpassed the bottle beer sales (Morean, 2009). The Hawaii brewing company in 1958 launched the first all-aluminum can (William & Duncan, 1994, p. 48). The aluminum material properties (formability) and the cost were better than for steel. Apparently, the steel-can makers feared the competition of the aluminum can. By 1967, other major beverage producers such as PepsiCo and Coca-Cola started using these cans (William &Duncan, 1994, p 48). Today, the aluminum has virtually displaced steel in all packages related to metal, mostly in the beverage containers. Reynolds initiated the two parts can method. The process is known as two-piece drawing and wall ironing (William & Duncan, 1994, p. 48-50). Figure 3 summarized the history of the beverage can.

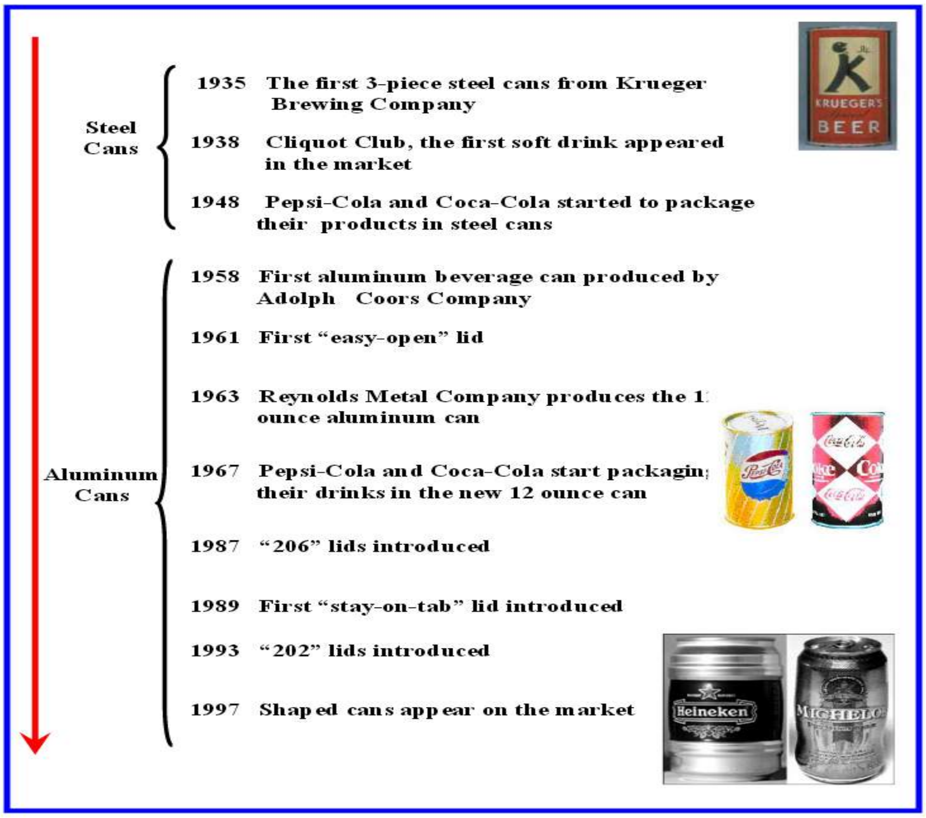

Figure 3. Beverage cans history (Liew, 2005, p. 18).

1.3.4 Lid of the beer can development history

The flat top can is more acceptable than the cone top can. The reason might have been the better economies of scale as a result of faster filling of the flat top can. The flat top can is easier to stack due to the flat top. By the late 1959, a new can was launched by Ermalfraze, it is self-opening (Morean, 2009). It has a pull lever which is connected to a perforated tab. Another name for this can is “zip top”. A pull ring opening was later introduced. However, the tabs were removable that wound up, littering the environment and causing injuries to consumers. A better design was developed by Reynolds in 1975; it was a sta-tab can with a non-detachable tab (Morean, 2009).

The can lid has a tab, which is used to open the can. It is mostly scored for easier functionality. Over the years, modification and improvement have been done with the lid; one of such is the reduction in its diameter. As the current beverage cans come in different sizes, so does the lid. The most used standard lid today is called “202” (Liew, 2005, p. 19). Nowadays, we have the can in various sizes and design. The most common beverage can used has a cylindrical shape. The table below shows various sizes and lids that are in circulation.

Table 3. Various can and Lid types (Liew, 2005, p. 21).

Aluminum Beverage Can Sizes (Oz)				Aluminum Beverage Can End Types and Sizes	
32	25	16	12	202	(2.25” diameter)
11.3	10	8.4	8	204	(2.38” diameter)
6.8	5.5	4		206	(2.5” diameter)

1.4 The aluminum can present design (cylindrical can)

This section describes the manufacturing of the beverage cans. The production process was documented according to United States of America market condition. The processes from the sheet making to the can production are explained below.

1.4.1 The can sheet production

The beverage can could be made out of a metal material such as steel and aluminum. For the aluminum beverage can, the manufacturing process starts by converting the metal ingots into the stock (for the can) and stock coil (for the lid) through the rolling process. The can stock is converted into can bodies and the lids stock coil into the lids at the can manufacturing plant (PE Americas, 2010). The process begins in hot mill rolling, aluminum ingot with an average value of 18 – 26 in (0.4m - 0.6m) thick and weighing approximately 15-30 metric ton is preheated to about 1000 degree Fahrenheit (537 degree Celsius) and passed through the hot reversing mill. Feeding of ingot into the reverse mill is to reduce the thickness and increase the length, as well as to solidify the ingot to become stab. At the reverse mill, the product moves in forward and backward motion between various rollers. After that stage, the stab is fed into the continuous hot mill for further thickness reduction to about less than ¼ inch. The metal is rolled into a coil (hot coil) and transfer to the cold mill section (PE Americas, 2010; Woodward, 1994, p. 6-9).

The cold milling, the metal (hot coil) can be heat treated. It could be annealed to alter the physical and chemical properties in order to increase the ductility and be more workable. One of the major improvements in the can production plant is the energy management system. Thus, the process of self-annealing is energy efficient as it does not require extra cost of investment in energy (PE Americas, 2010). During this process, the coil is fed through the rollers and the coil gauge is reduced to 0.012 inches, which is the requirement of the can makers. The coils are slit and cut into the customer specification (Karhausen, 2003, p.368-378). A proper packaging is done for the coil to prevent damage during transportation. The flow chart is shown in figure 4.

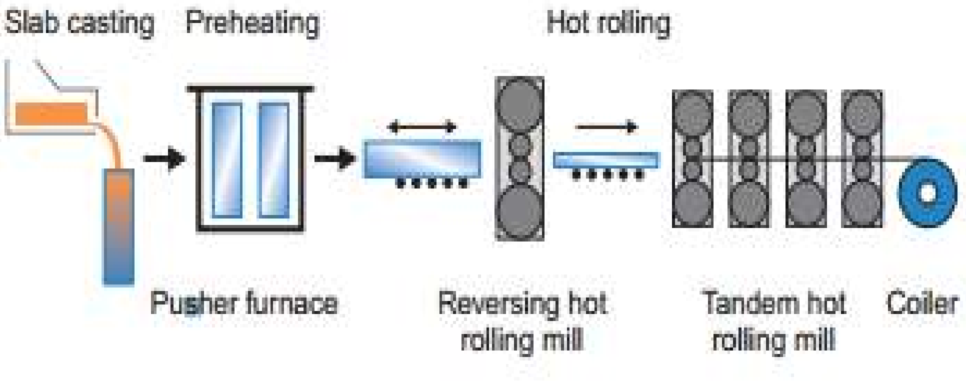

Figure 4. Conventional hot strip production (Achenbach Buschhütten, 2014).

Basically, the sheet rolling is determined by the final use or the final product of the sheet. In relating to the production of beverage can, the can sheet end product are the body component and the lid. The main difference between the sheet making for the can body and the lid is the addition of the coating step to the lid. The figure 5 shows the flow chart of sheet rolling of the can components. According to the study done by PE Americas (2010), in term of weight, result shows that the ratio of the lid to the body's production is approximately 22 to 78.

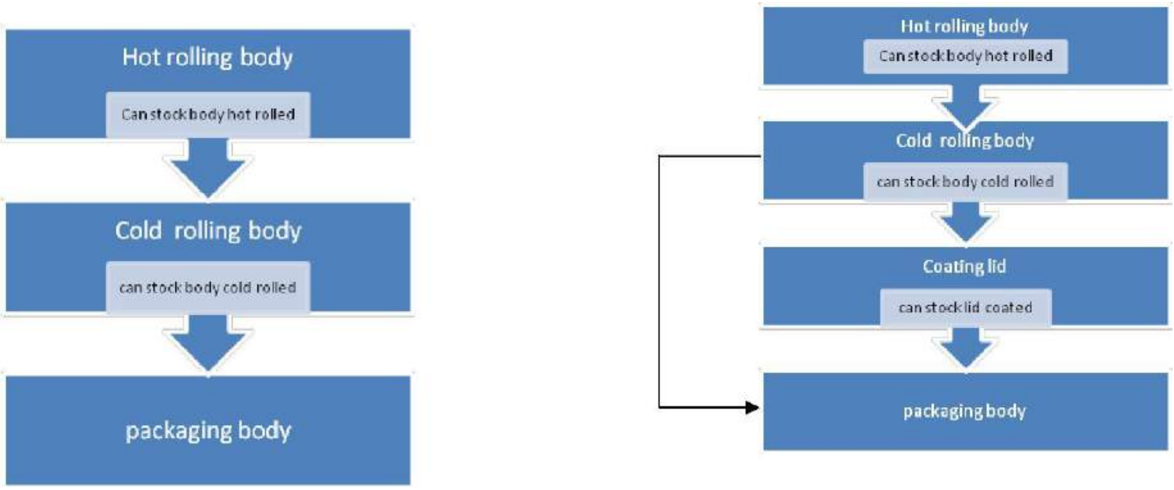

Figure 5. Can body sheet rolling flow chart (left) and can lid sheet rolling flow chart (right) (PE Americas, 2010).

1.4.2 The Can Manufacturing Process

The can is mostly made at the can manufacturing plant. The coil is shipped from the rolling mill plant. At the plant, the coils are set in a position to be fed into the cupping press. Then it is unwound and lubricated, cool and fed to the press (Blaisdell, 1988, p.1257; Joseph, 1988, p. 1673-1682). In the cupping press, the coil is pressed into cups by stamping with blanks or discs. During the various stages, scraps are generated. They are shipped to the recycling plant. A further series of operations such as forming, punching, and ironing are done on the cup blank to form cup profile depending on cans specification and dimension (Blaisdell, 1988, p. 1257; Joseph, 1988, p. 1673-1682; PE Americas, 2010). The parameters that affect the can formation include the die angle, friction coefficient, clearances etc. The strain- hardening exponent value affects the sheet metal forming process; more force might be required for ironing if the value is low (Folle et al, 2008, p. 347). Figure 6 shows some of the steps from 1-4.

The trimming of the top is done to have the flat top shape of the current cylindrical can. Thereafter the cans are washed thoroughly to remove the dirt and stain. After the washing, they are dried in the oven (PE Americas, 2010). The printing is done on the can. The printing on the outside serves as the label for the product. Also, it serves as a protection layer for the aluminum. Using up to 6 different combinations of color before a thin film of lacquer is applied. Lacquers are applied to the bottom of the can for easy motion on the conveyor. Then, it is cured in the oven. Another film of lacquer is applied to the internal surface of the can to establish a barrier layer. To protect the content (beverage) from the metal contamination such as taste and color. This is necessary as quality preventive measure. The cans are finally cured in another oven (PE Americas, 2010).

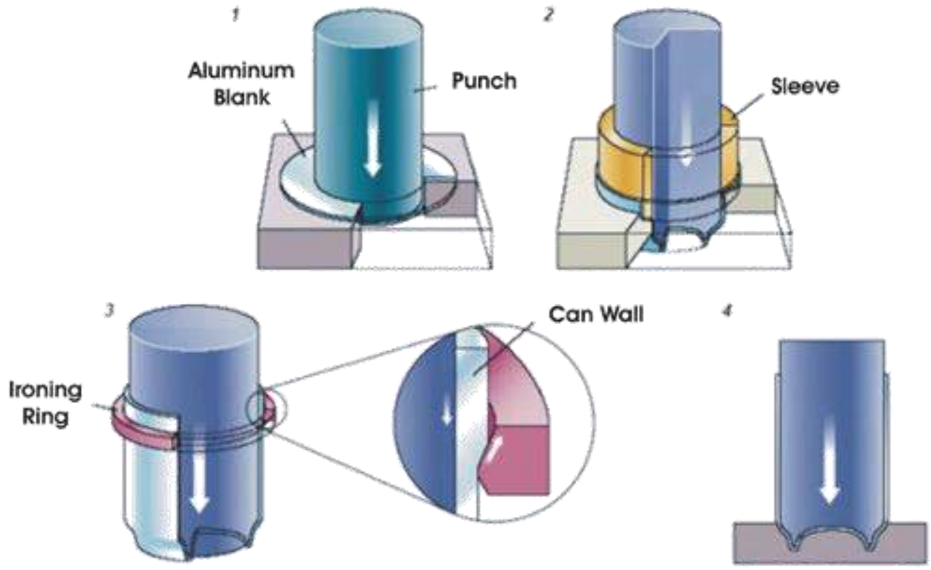

Figure 6. Aluminum beverage can drawing and wall ironing process (William & Duncan, 1994, p. 50-51).

The cans are transported to the necking section using the conveyor. The necking of the can is an ode of tensile deformation; this is a disproportional localization strain in a small region at the top (Tsuchida, Inoue & Enami, 2012, p. 133-136). After the top diameter is reduced, the flange is formed. The flange is a part that forms the sealing with the lid. The can is transported to the quality section. The cans are inspected using the quality inspection equipment and standard. The quality certified cans are stacked onto the pallet for onward shipment to the beverage plant for filling. The cans that do not pass the quality checks are tagged defected end product and shipped to the recycling plant. The cans stacked are separated in layers using the corrugated paper or plastic sheet, then bound together with a plastic material. Finally, the entire pallet is wrapped using the plastic material. This is for protecting the can from contamination and deformation during shipment and storage (PE Americas, 2010).

The current can is made up of the body and the lid and they are manufactured from different aluminum alloys. Lid is made out of Aluminum alloy Al 5182, it contain more magnesium and less manganese. The can body is made out of aluminum alloy Al 3004 (Liew, 2005, p. 9). The lid is stiffer than the can. The composition of the aluminum alloys is shown in figure 7.

ALLOY-TEMPER	USE	COMPOSITION (wt %) MAXIMUM UNLESS SHOWN AS A RANGE					LONGITUDINAL MECHANICAL PROPERTIES		
		Cu	Fe	Mg	Mn	Si	UTS (ksi)	0.2% YS (ksi)	ELONG. (%)
3004-H19	CAN BODY	0.25	0.70	0.8-1.3	1.0-1.5	0.30	43	41	2.0
5182-H28	CAN END	0.15	0.35	4.0-5.0	0.2-0.5	0.20	55	49	7.0
5042-H19	TAB	0.15	0.35	3.0-4.0	0.2-0.5	0.20	50	47	5.0

TALAT | Composition and Properties of Aluminium Alloys used in Can Making | 1301.02.07

Figure 7. Composition and properties of aluminium alloys used in can making (Woodward, 1994, p. 9).

The stocks lid is washed and cleaned after cold rolling. It is shipped to the manufacturer. The lid can be manufactured from the scrolled (sheets or coil). For the lids manufacture from coils, the coils are fed into the stamping machine. The major steps are stamped at the end, the edge of the shell is curled, then the sealing compound is applied, the tab is stamped and the end feature is stamped onto the ends. Finally, the lid is completed by joining the tab to the end. The figures 8 and 9 are an illustration of different shape phases and the anatomy of a modern can (PE Americas, 2010; Blaisdell, 1988, p. 1257; Joseph, 1988, p. 1673-1682).

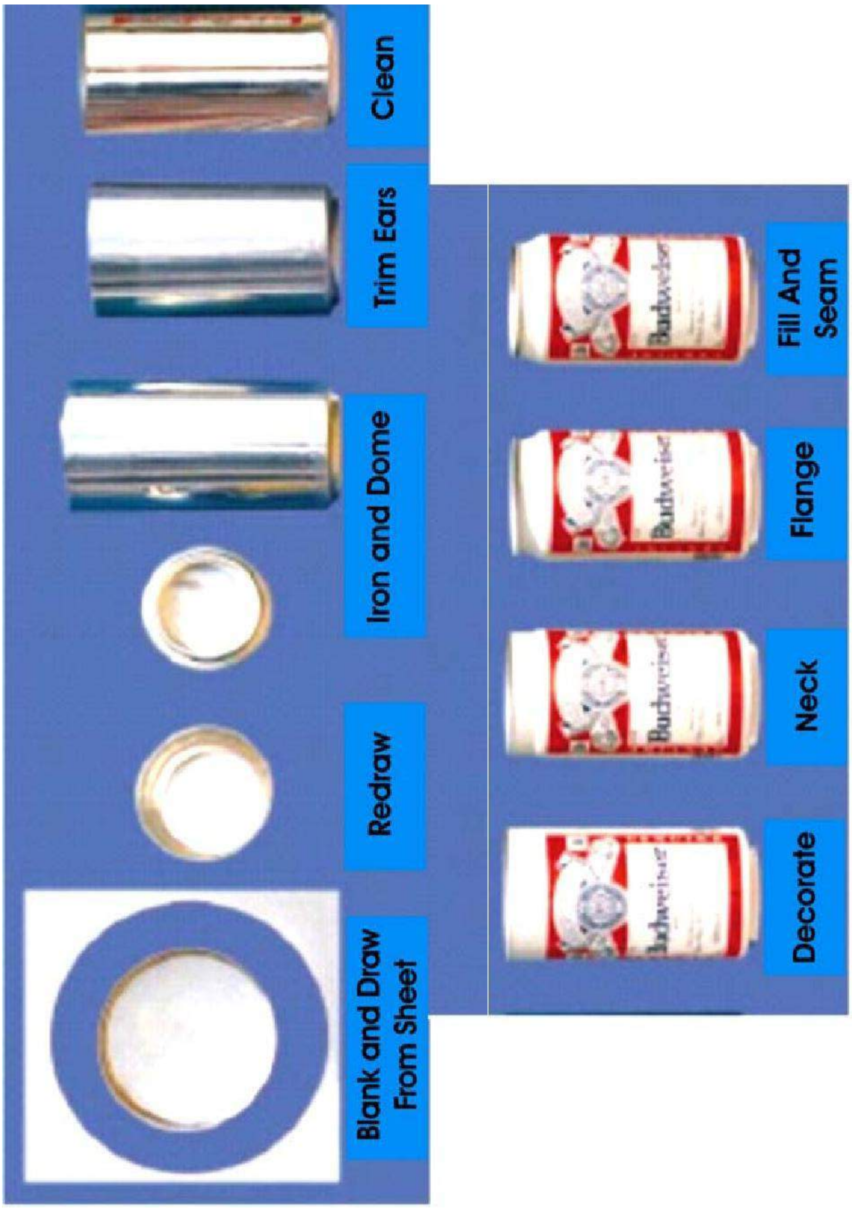

Figure 8. Can shape phases (William & Duncan, 1994, p. 50-51).

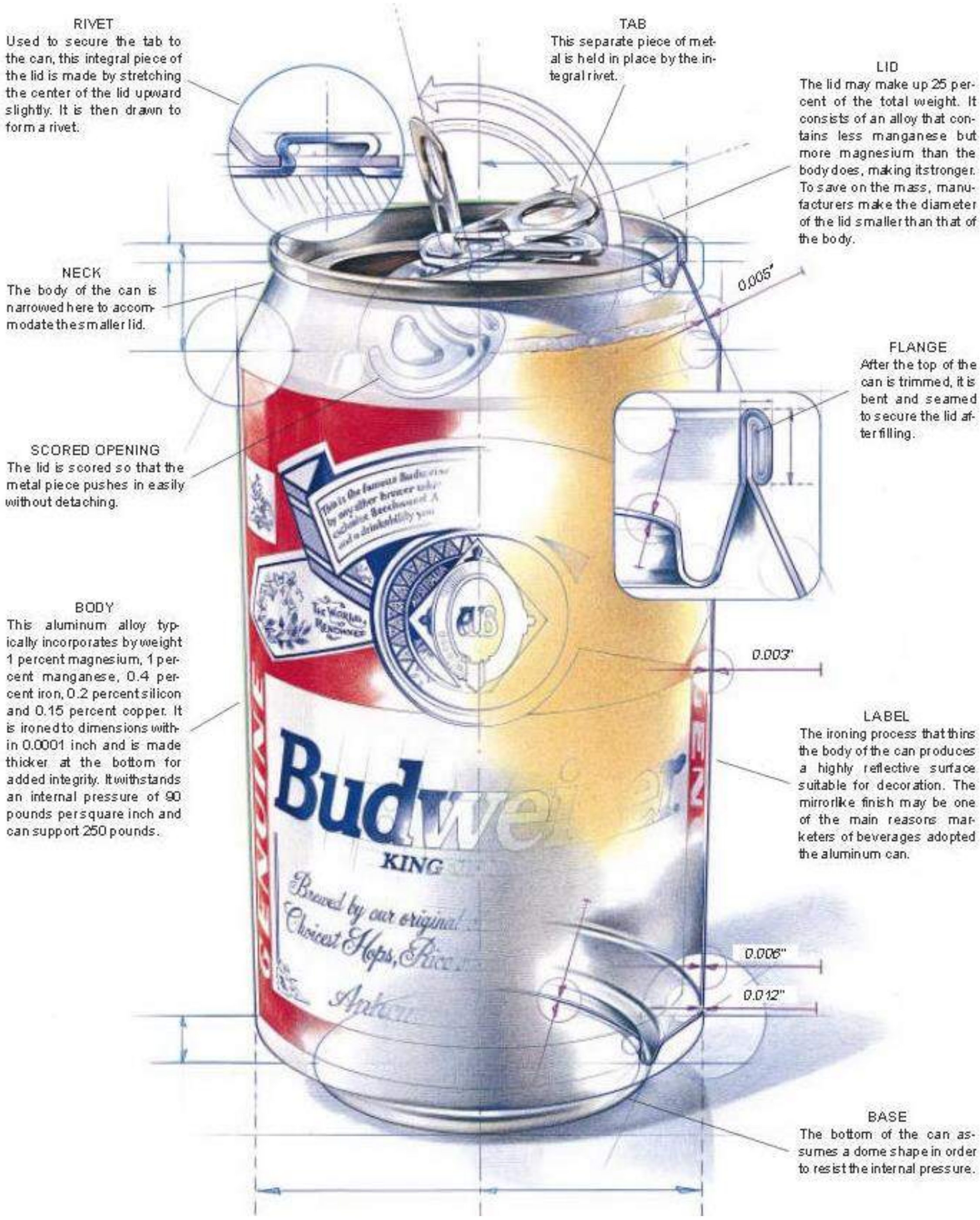

Figure 9. The anatomy of a modern can (William & Duncan, 1994, p. 49).

1.4.3 The Current can palletize

The number of layers of cans in a pallet can vary. It depends on the can size, the manufacture and the geographical location (REXAM, 2014). The cans are stacked similarly to the figure 10. Appendix 1 shows various pallet sizes and standard pallets for cans used by the REXAM can company. It could be noted that the number of layers varies with the cans sizes, also the pallet dimension and material varies with the number of cans that could be stacked on it. Invariably, more cans are likely to be stacked on the wooden pallet than the plastic pallet of the same size cans.

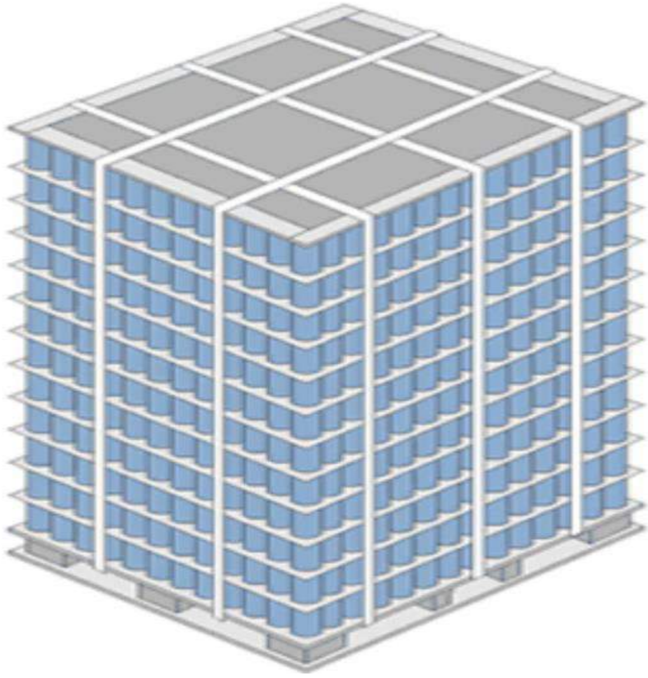

Figure 10. Can palletizing (REXAM, 2014).

1.5 The can maker and filling company distribution

Basically, the beverage industry is witnessing increase in sale, which translates directly to the increase in can demands. For illustration, in 2013, the total numbers of drink cans delivered was almost 60 billion in the European market. In United Kingdom, over 9.5 billion drink cans was delivered. Figure11 shows that there has been an increase in the can supply (Beverage Can Makers Europe, 2014).

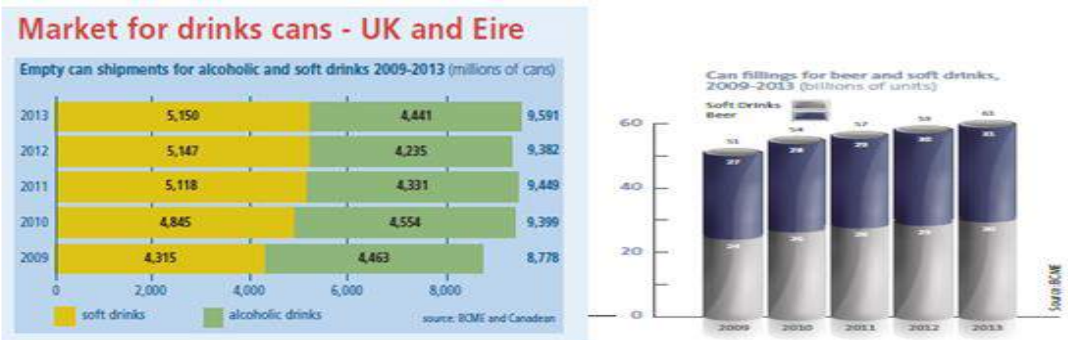

Figure 11. Market for drinks cans (Beverage Can Makers Europe, 2014).

Basically, the can´s makers are mostly different from the filling company. The three major can makers in Europe are Rexam, Ball packing Europe and Crown Beverage can EMEA. Although these major manufacturer have other companies at other parts of the world. The Appendix 2 shows the major can maker locations, their material and number of production lines in Europe. Figure 12 also shows some of the location of the can manufacturer in Europe (Beverage Can Makers Europe, 2014).

Figure 12. The can manufacturing plant on the map (Beverage Can Makers Europe, 2014).

The needs for optimizing the supply chain could be established from the map. The can making plants are located based on the availability of resources and market. The can makers are not always located closely to the filling plants.

1.6 The plastic cup (conical shape)

The plastic cup could be categorized as a packaging due to its function. It is used to hold liquid (beverage). It is made from plastic and most of the cups have SPI resin identification; which states more about the recycling. This will allow efficient separation of different polymer type for recycling. In the plastic industry, the plastic product can be produced using various manufacturing processes. Most plastic cups are made using the injection molding process. The injection molding machine comprises of the injection unit, clamping units, mold cavity etc. Figures 13 and 14 show the process steps and the injection molding machine respectively (Wagner, Mount & Giles, 2014, p. 3; Müller et al., 2014, 705).

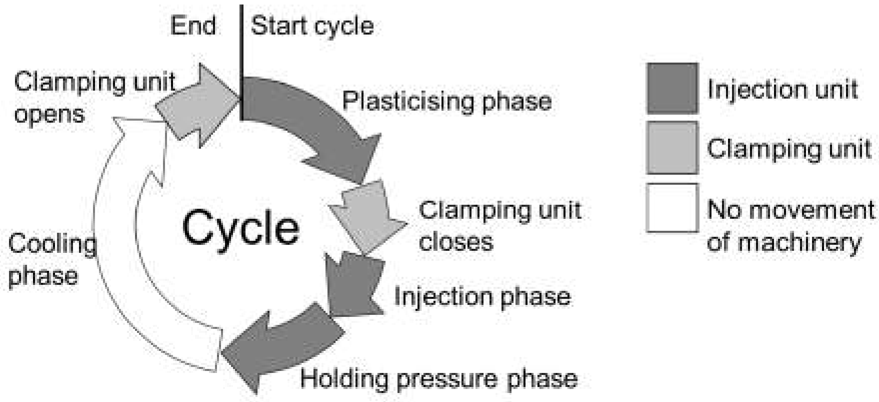

Figure 13. Schematic representation of the process steps in the injection moulding (Müller et al., 2014, 705).

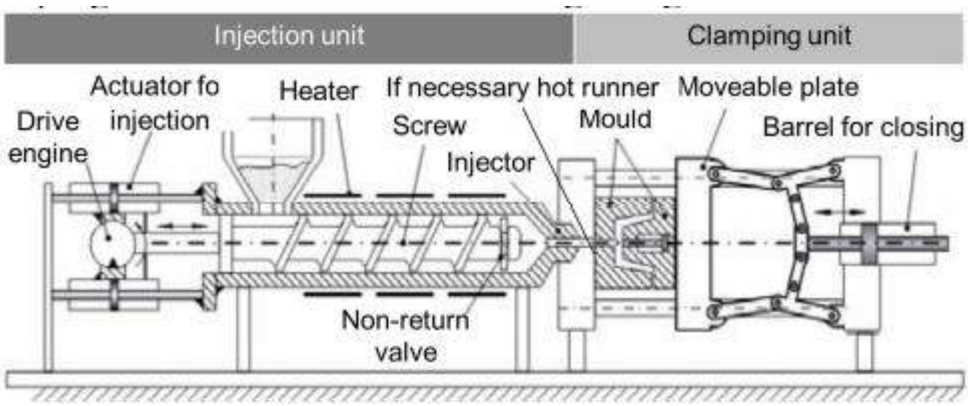

Figure 14. Schematic view of an IMM (Müller et al., 2014, 705).

In the injection, the raw material (plastic granule) is poured into the hopper to be mixed, and then softened or melted to a mixture in a barrel to be injected into a mold under high pressure. The molten plastic will take the shape of the cavity; the pressure is maintained for the product to change from the molten state into the solid state. Finally, the mold is opened to release the product (plastic cup). Quality check is done for the plastic cup; the cups are counted and stacked into each other. The number of cups per stack depends on the manufacturer. Each cup stack is bagged in a plastic pouch. The pouches are packed into a cardboard box; thereafter the boxes are stacked on a pallet.

The conical shape of the plastic cup increases the number of cups that can be arranged in a pack and box. Thus the conical shape helps with the space optimization. Figure 15 shows an example of stacked cups. The optimization results into a positive outcome in cost and carbon emission as well as other factors.

Figure 15. Stacked plastic cups (Shuangtong Daily Necessities, 2014).

For over eight decades, various studies have been done on plastic cups. One of the patents about the plastic cup and its stack ability is the patent no US 3519165A (1970) (contained in appendix 3). Pat US 3519165A (1970) invention relates to improving the nesting characteristic of the cup as the plastic (container) is designed to be nested close to one another; for space optimization in storage. However, a stacked cup might be affected by compression loading, which could cause defects and also the cup might not easily be separated. Thus the invention was also providing a stacking device in the wall of the cup. (Pat. US 3519165A, 1970.) This is assumed to facilitate the cup separation from the nested stock. In applying the plastic cup conical shape for the aluminum can, one of the solutions to the problem could be this patent.

2 METHODS

In this section, the methods and the systems used in answering the research questions are discussed. In order to provide answers to some of the research questions, a well-known method and approach in the scientific community; the mixed method approach through the triangulation method was used. The concept of the conical shape of the plastic cup was applied, a scenario was created to calculate the emissions during empty-can shipment and questionnaires were used to investigate the study.

2.1 The mixed method

The mixed method through the triangulation method is a method of comparing the findings from different sources to check if there is a correlation in the total group result collated. In the correlated result, it is a hope that it would further strengthen the validity of the findings. The triangulation is shown in the figure 16. The criteria given by Creswell (2003, p. 3-10) for choosing the appropriate method was considered. They are sequences of implementation, the scale of preference, integration and the theoretical overview.

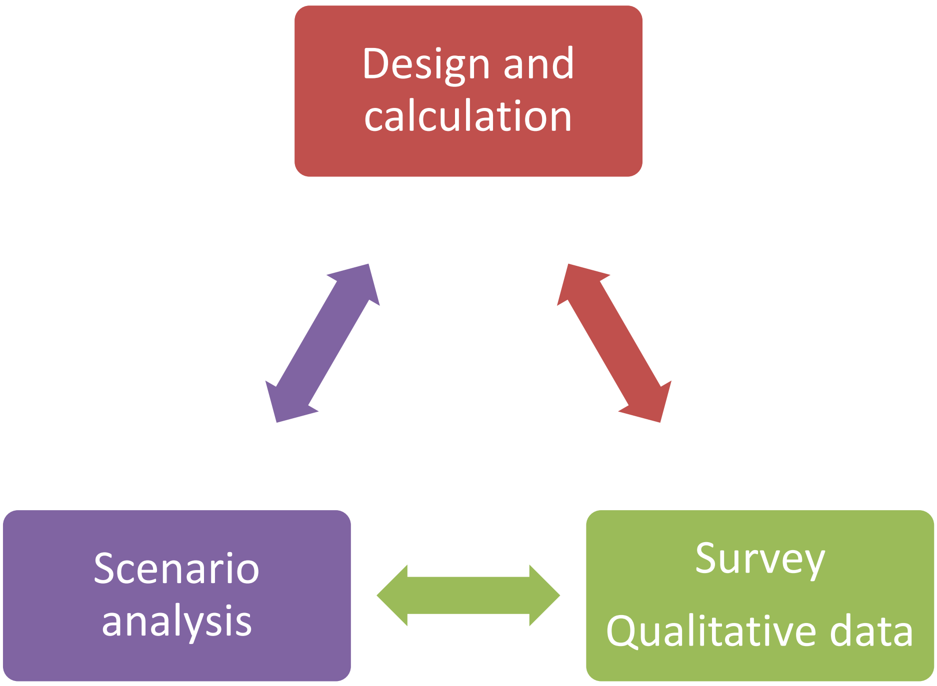

Figure 16. The triangulation model.

In product designing research, qualitative and quantitative methods are widely used. The mixed method helps in understanding the complexity of the data and offers a detailed and comprehensive result that inquiries can be made upon (Bryman, 1996; Creswell 2003). The mixed method combines the elements of qualitative and quantitative research approaches for understanding and correlation (Johnson, Onwuegbuzie & Turner, 2007, p. 129). Combining both methods offsets the individual methods weaknesses and enhances their strength. Thus, the data from each method will be fused (Zou, Sunindijo & Dainty, 2014, p. 316-326).

2.2 Concept application

Using the similar shape of the plastic cup, it was suggested that a conical shape of the beverage can could be a solution for the space optimization of empty beverage cans during transportation. To check about the possibility of the design for aluminum beverage can a finite element method tool was used. Also, a study about the stakeholder's perspective on the new idea was done.

The body shell thickness of the current beverage can (cylindrical shape) vary from 0.075 mm to 0.3mm depending on the manufacturer (Liew, 2005, p. 61). The thickness varies with the part, the bottom is the thickest, followed by the top and the thinnest portion is in the middle. Basically, the structural performance of any beverage can design is critical. A beverage can should be able to withstand internal gas pressure of 620 KPa and the top load of 113.3981 kg. (Liew, 2005, p. 60.) The cone can was drawn with Solid Works and was modeled with aluminum alloy.

However, in order to get a new dimension for the conical beverage can, some of the existing dimensions of the cylindrical can were used. For the 330 ml can, the diameter of the beverage can and the base (stand diameter) from the REXAM beverage can given in appendix 4 was used. The unknown dimension concerning the conical shape as shown in figure 17 was the height. The two dimensions of the cylindrical can (the two diameters) were retained so that the new design comparison with the current design might be easy. The equation 1 was used for the calculation.

$$V = \frac{\pi h}{12}(d^2 + db + b^2) \qquad (1)$$

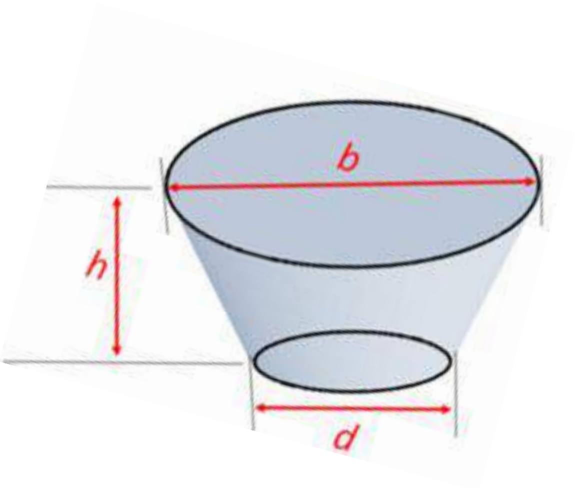

Figure 17. Truncated cone shape and formula.

According to appendix 4, the dimensions are b=66.3 mm, d= 47.29 mm. The headspace estimation was done, the head space should not exceed 2ml, and therefore, the assumed volume for the 330ml can will be 332 ml, therefore using the equation 1, the value of the height was calculated to be 129.11mm. Appendix 5 gives details about the conical can.

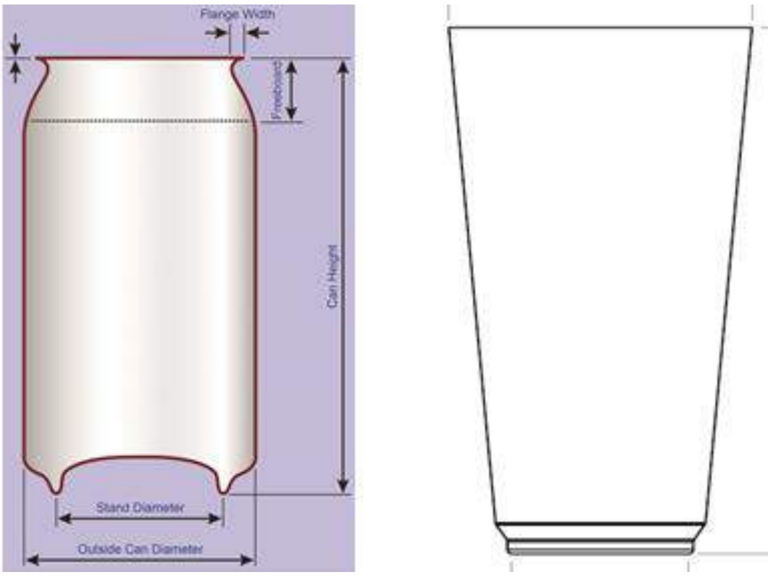

Figure 18. Dimensioning variation of the can (REXAM, 2014).

2.3 Scenario

The REXAM Fosie, a major can maker in Europe is located at Stenåldersgatan 4, 213 76 Malmö, Sweden, the plant is assumed to be the only Rexam plant in Sweden. It is located in Malmo, which is about 623 km from the Sweden capital city, Stockholm. Assuming that they are to supply the can size (330 ml) for the filling company factory which is located at Stockholm (Coca-Cola Enterprises Sverige,Dryckesvägen 2C, 136 87 Haninge), what could be the effect of shipment of the current can on the transportation carbon emission. The map is shown in the appendix 6. Also, it is likely that the truck will be used for the transportation due to limited or non-proximity of the rail line. Assuming that they will only ship the can body.

The rate of emission was calculated using the EcoTransIT world application (EcoTransIt World, 2011, p. 18-20). It is an approved environment impact assessment tool. The online (internet based) application was used for this research. It was used to calculate the environmental impact of the freight transport and to analyze the result. The emission parameters cover the air pollutant and the greenhouse gas. The air pollutant includes the nitrogen oxide (NO_x), sulphur oxide (SO_2), non-methane hydrocarbon (NMHC) and the particular matter. The calculations were based on the equations 2-4 (EcoTransIt World, 2011, p. 18-20).

$$ECF_{tkm,I} = \frac{ECF_{km,I}}{CP \times CU} \quad (2)$$

$$EMV_{tkm,I} = \frac{EMV_{km,I}}{CP \times CU} \quad (3)$$

$$EMV_{tkm,I} = ECF_{km,I} \times EMV_{EC,J} \quad (4)$$

Where,

- $ECF_{tkm,I}$ is the final energy consumption per net tonne km for each energy carrier i [MJ/tkm],
- I is the index for energy carrier (e.g. diesel, electricity, HFO),
- $ECF_{km,I}$ is the final energy consumption of vehicle or vessel per km (normally depends on mass related capacity utilization) [MJ/tkm],
- CP is the payload capacity [tonne],
- CU is the capacity utilization [%],
- $EMV_{tkm,I}$ is the vehicle emissions consumption per net tonne km for each energy carrier [g/tkm],
- $EMV_{km,I}$ is the combustion related vehicle emission factor of vehicle or vessel per km (normally depends on mass related capacity utilization) [g/tkm] and
- $EMV_{tkm,}$ is the Vehicle emissions per net tonne km for each energy carrier i.

(EcoTransIt World, 2011, p. 18-28).

For the calculation, the scenario calculation was done for the current cylindrical can, and then the scenario was calculated for the conical can. Also, as a result of optimization resulting from the conical can, the scenario was used for the amount of beverage can (cylindrical) that will be supplied for the equivalent amount of the conical can optimization. This will represent the comparison of the two designs (the cylindrical and the conical shape).

2.4 Qualitative and Quantitative method

The complexity in this practical research is to get the beverage can's stakeholder perspective on the proposed new conical can and measuring their interest toward a sustainable package. The quantitative research in the form of a questionnaire filled by the stakeholder in the can industry will provide numerical evidence on which the statistically analysis could be performed. The qualitative part in the form of an interview will provide complimentary information to the quantitative method. Another benefit of combining the qualitative research is to develop analysis, which could lead to new data generation. This new data could be the basis for new information that could be achieved from the application of the triangulation. (Zou et al., 2014, p. 324.)

For this particular research, the inter-method mixing strategy between the qualitative research in the form of interview and quantitative questions in the form of a questionnaire was applied. The table 4 depicts the research objectives and approach used (Rattray & Jones, 2007, p. 234-243).

Table 4. Research objective.

Question-naire	Objective	Data source	Approach	Method	Form of Analysis
1	Investigating the beverage can's stakeholder perception about the conical can shape.	Primary data	Quantitative and Qualitative approach	Question-naire and interview	Statistical tools and qualitative analysis
2	Investigating the beverage can's stakeholder perception about the conical can shape and what could be the obstacle to its introduction	Primary data	Quantitative	Question-naire	Statistical tools and qualitative analysis

2.5 Questionnaire design

The questionnaire designed was developed using the rules for its content, layout and construction (Rattray & Jones, 2007, p. 234-243). Two questionnaires were developed.

They contain main section as well as the introduction and the follow-up. The section is in line with the research objective in table 4. The actual questions can be found in appendix 7 & 8 respectively. The table 5 explains the reason behind the questions and the rational. Also, it has the measurement scale that will be used and the intended target group .(Raderbauer, 2011). The target groups are the intended participants for the questionnaire. The survey was hosted and design on an online survey tool called Surveymonkey (surveymonkey, 2014.)

Table 5. Questionnaire 1 structure for the Consumer about the Conical Aluminum Can.

Section	Question and Rationale	Measurement scale	Target group
Introduction	Brief explanation about the research objective and confidentiality		
Objective 1	To further understand the stakeholder perception about the conical can. The perspective is considered from the design (look) of the product. It is presumed that if there is high acceptability of the shape, this could be a positive direction for further research. Considering the sustainability, the consumer knowledge and interest will be check perspective, The aim is to identify their opinion as this might lever of acceptance of sustainable consumption	Closed question with response alternative; Yes or No Open factual question Five and four point Likert scale	The consumer
Request for follow up			

Table 6. Questionnaire 2 structure for the industry about the conical aluminum can.

Section	Question and Rationale	Measurement scale	Target group
Introduction	Brief explanation about the research objective and confidentiality		
Objective	Understanding about the stakeholder perception on sustainability, if there is less interest, this could serve negatively for sustainable product and vis a vis. Weight their significance. Considering the engineering perspective, the obstacle and limitation from the manufacturing section is considered. The aim is to identify the obstacles	Closed question with response alternative; Yes or No Open factual question Five point Likert scale	The can maker, The beverage company, packaging companies
Request for follow up			

The pilot project was done with seven respondents. The respondents are an expert in the packaging technology, an expert in the information searching, experts in industrial management and others. The responses were collected within five days. The respondents gave various feedbacks about the questionnaires. One of the feedbacks was about the length of the introduction section, being too long. Some of the suggestions from the pilot project were used to prepare the final questionnaires. Also, the result from the questionnaire was analysis with the objective of the questionnaire. Also, based on the respondent result, the questionnaire for the consumer was not misleading, although, some are of the opinion that the details about the benefits of the conical should be given. However, based on literature, it will be misleading if the details of the result were incorporated into the questionnaire.

The actual questionnaire was launched on the 12th of December 2014. The two questionnaires were sent to the intended groups. The questionnaire was in electronic format and the response was collected electronically. The means of communication was through the electronics format for both questionnaires. A direct message from the Surveymonkey website was sent to selected groups. Also an email was sent to the target group which contained the links for the online format. Also, social media post was used for the questionnaire 1. Most of the respondents for questionnaire 1 were students or employees of the university. Twenty participants were selected for the questionnaire 2, which was made specifically for the industry. The participants are the can makers, the beverage companies, the media in beverage packaging etc. An email was sent to them at the launch of the survey, unfortunately, no response was gotten after one week. A reminder message was sent to them after a week as planned. Still no response was gotten. Then a personal email was sent to the participant. Thereafter, there was one response.

The rate of filling the questionnaire 1 which was made specifically for the consumer was high. Within one week, most of the chosen respondents had participated in the survey. The responses were collected within two weeks starting from the sent date. A reminder was sent in a week after the sent date.

3 RESULTS

The results were classified into three sections. The sections include the redesign of the beverage can, the scenario about the carbon emission and the responses on the questionnaires.

3.1 Innovative beverage can design for reduction of carbon emission during empty-can transportation

After detailed analysis of the aluminum beverage can, it was noted that a lot of research and result has been achieved in the reduction of the weight of the can. There was research in the seaming of the can. Also there has been research about the material selection for improving the recyclability. However, little was seen in the space optimization of the empty can for transportation. It was noted that the space optimization might reduce the amount of carbon emission resulting from transportation, thus making the beverage can to be more sustainable. The space optimization will be beneficial to the economy and society. In order to establish the applicability of the space optimization, the concept of design for sustainability from the product perspective was used.

The redesign of the beverage can was done by considering the existing design and introducing a subtle innovation and concept from a similar package design. The concept of design for sustainability was applied to the 330 ml aluminum beverage can. It is selected based on its market share. It is the most commonly used size in the beverage industry. Also, it was assumed that applying the design concept to the size might give result that will be used to check the suitability of the product.

Using the six stages of material flow of the 6R concept; Recover, Reuse, Recycle, Redesign, Reduce and Recycle (Jawahir et al., 2006, p. 4). out of which 3R (Redesign, Reduce and Recycle) were identified for the space optimization of the product design of the aluminum beverage can. However, the focus was on the Redesign. Presently, the aluminum can is considered to be a good image for recycling. Thus, the aluminum cans usage and growth are far ahead of the steel cans, although the steel can be recycled, but in term of weight, cost and recycling rate, the aluminum is preferred (PE Americas 2010). The Aluminum is four times more valuable than other packaging recycle material (Tabereaux, 2014, p.839).

As discussed, one of the unsustainable features of the beverage can is the issue of space optimization during transportation of empty cans. According to figure 10 in Chapter 1, it could be seen that the can are stacked on the top of each other with a material (paper or wood) separating the layers. The data from appendixes 2 and 9 proves that the trucks are less used due to the space constraint. Imagine a truck that was designed with total capacity of 39000 kg being used for less than 25% of its capacity according to scenario 1 calculation. It thus reinforces the need for space optimization of the beverage can. However, little could be done on the current cylindrical shape space optimization.

The concept of the proposed design is based on the plastic cup conical shape. Although considering the modification of the beverage can dimensions and design, there could be the need for revamping of the manufacturing processes. However, it could be noted that the new design concept is based on an existing product which thorough researches have been achieved. As stated, the aluminum beverage can is a well-developed and researched product. A sample of the current can has a stay on lid, dome-shaped surface at the bottom and a cylindrical body shape, the figure 19 and Appendix 5 shows the details and transformation.

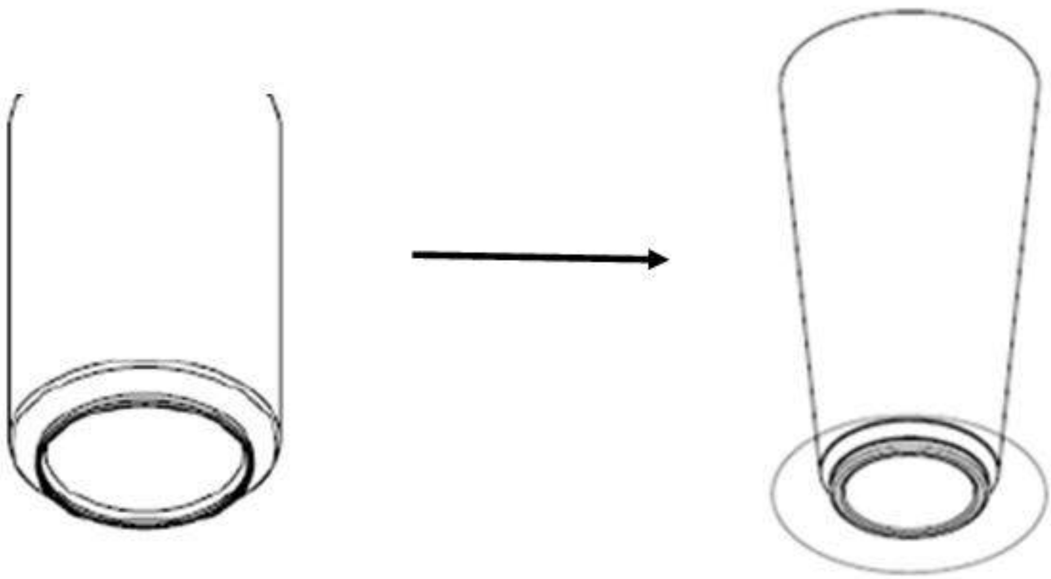

Figure 19. The cylindrical and conical beverages can: on the left the current shape and on the right the proposed shape.

The SolidWorks design application was used to design the package and for the structural performance. The internal pressure of 0.62 MPa and top load of 113.4 kg was used. This is the criterion necessary for the structural performance of any beverage design (Liew, 2005, p. 60). The figures 18 and 19 show the result.

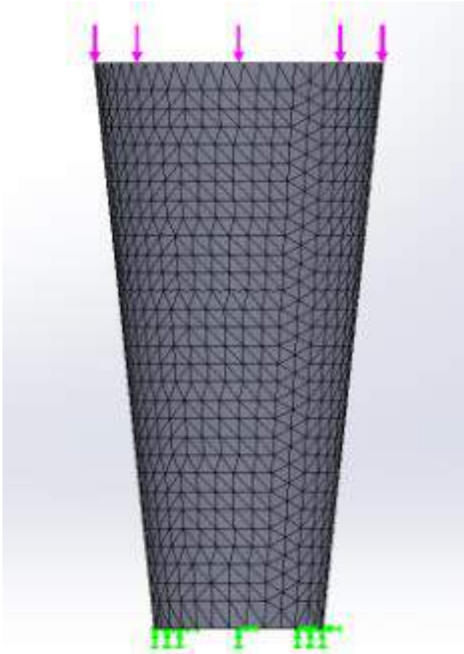

Figure 20. The simulation.

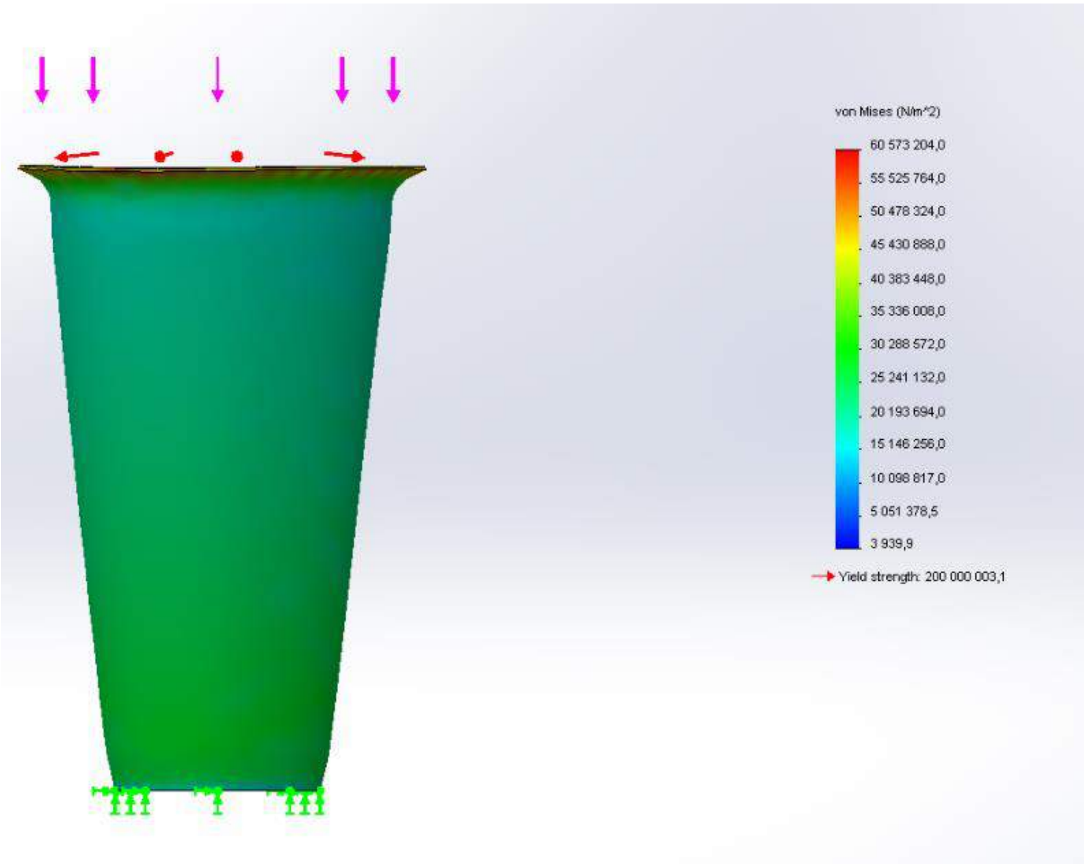

Figure 21. The simulation.

3.2 Calculation of the carbon emission during empty-can shipment (cylindrical can)

Based on the scenario, the emission was calculated using the standard can sizes (330ml) made from aluminum and produced by REXAM's plant in Sweden (Fosie plant) (REXAM, 2014); the scenario was calculated to know the influence of the cans stacking in the current design on the carbon emission during transportation. Firstly, the current pallet information is shown in figure 22. The dimensioning of the pallet is shown in figure 23.

PLANT: FOSIE - Aluminium Cans

PALLET DIMENSION mm Length x Width	CAN SIZE ml	NUMBER OF LAYERS	CAN LAYER CONFIGURATION Length x Width (Number of Cans)	CANS PER LAYER	CANS PER PALLET	NOMINAL HEIGHT mm	NOMINAL WEIGHT, kg ALU STEEL	TOP FRAME MATERIAL	PALLET MATERIAL
1350x1200	330	22	23x17	391	8602	~2730	~155	Wood	Wood
SWEDISH	500	15	23x17	391	5865	~2710	~135		
1250x1180	330	23	18x20	360	8280	~2809	~155	Steel	Wood
GERMAN	500	16	18x20	360	5760	~2843	~135	Steel	Plastic
1420x1120	330	22	20x19	380	8360	~2700	~145	Wood	Wood
DUTCH/SPAIN	330	22	20x19	390	8580	~2700	~147	Steel	Wood
	500	15	20x19	380	5700	~2665	~135	Steel	Plastic
	500	15	20x19	390	5850	~2665	~137	Plastic	Plastic
1440x1120	330	18	21x19	399	7182	~2223	~130	Wood	Wood
ITALIAN	500	14	21x19	399	5586	~2497	~130		

Figure 22. REXAM plant information (REXAM, 2014).

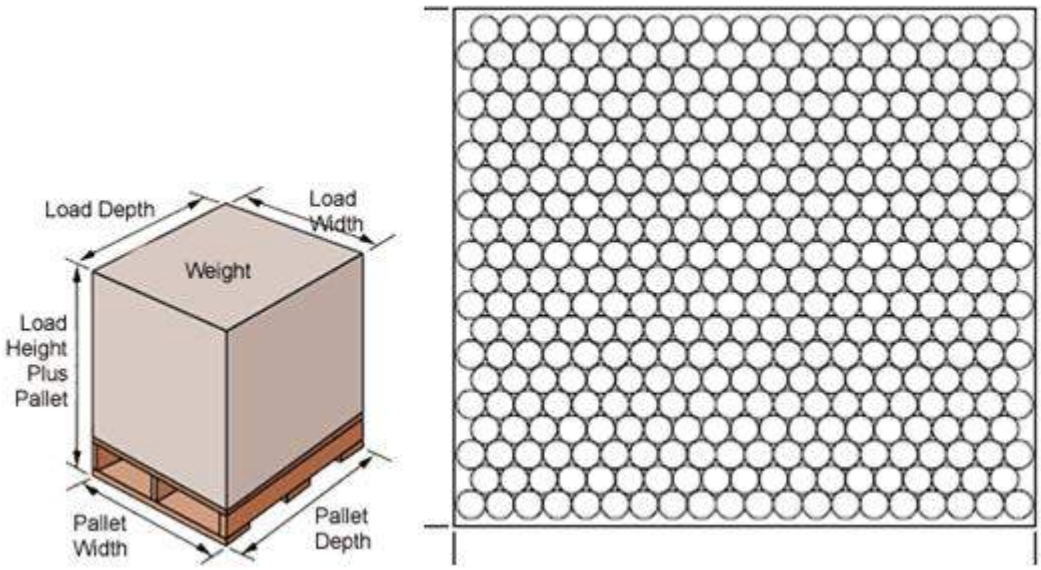

Figure 23. Example of can pallet information and the top view of the pallet.

Mathematically, the number of cans on pallet will be the product of the can layer and the number of can per layer. Whereby, the number of cans per layer will be the product of number of cans on the width and the number of can on the depth. The calculations are applied in the scenario. According to the information provided in appendix 1; the information about the pallet for the 330 ml can sizes produced in Fosie plant for the scenario analysis is given in table 7.

Table 7. Cylindrical can scenario information according Rexam (REXAM, 2014).

CAN SIZE (cylindrical)	330 ml
Total no of can per pallet	8602
No of pallet per journey	20
Total can per journey	172040

Using the information provided in appendix 9: truck dimension. The euro liner truck in figure 24 would have been a good option for the transportation, however, due to the internal height which is lowers the pallet height, the best option available might be the MEGA HIGH CUBE trailer. Table 8 gives information about the trailer.

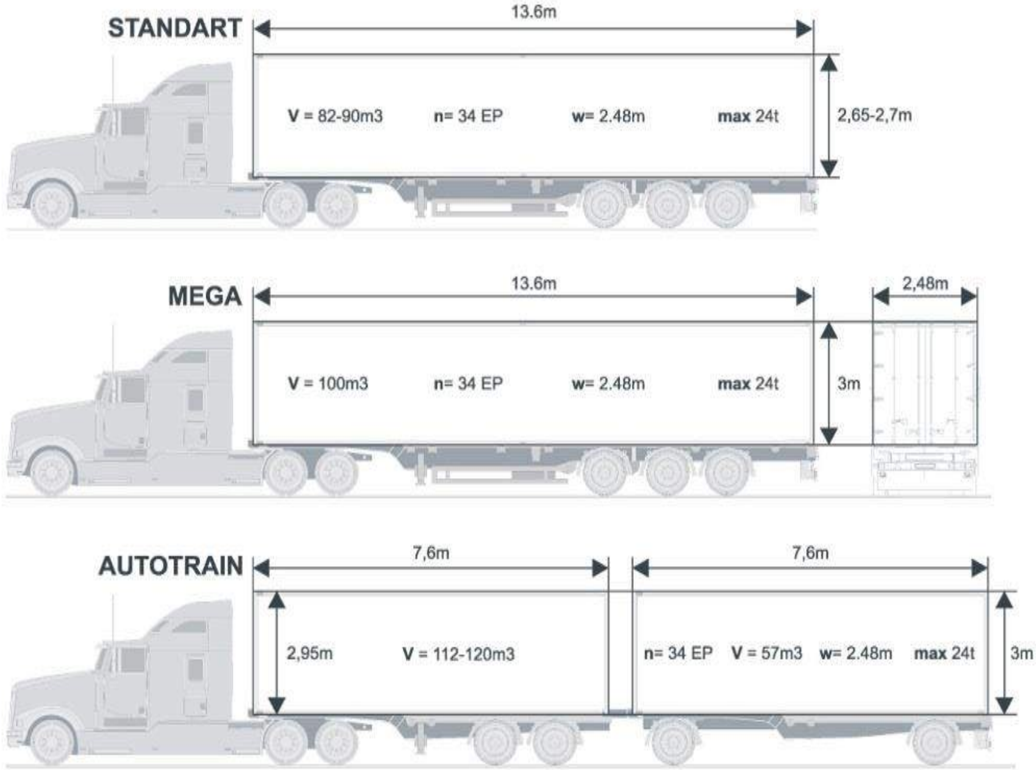

Figure 24. Truck dimension (ABIPA, 2012).

Table 8. Mega (High Cube) trailers truck dimension (ABIPA, 2012).

Internal length	13.62m
Internal height	3m
Internal width	2.48m
Tare	74000 kg
Design gross weight	39000kg

The total volume of the pallet is the product of pallet dimension and pallet height (4.42m^3). The volume of the truck (internal volume) equals to the product of internal height and internal width and internal length. Therefore the volume of the truck is 101.33m^3. In the situation of proper optimization of pallet dimension, the truck ought to accommodate; Number of pallets in the truck should be the Volume of truck divided by volume of each pallet, which would be 22.91 pallets. However, that cannot be possible; using the ratio of the width of the truck to the width of the pallet and the depth of the truck to the depth of the pallet, the truck can only accommodate 20 pallets. The arrangement is shown in table 9.

Table 9. Pallet arrangement in the truck.

Pallet 1	Pallet 2	Pallet 3	Pallet 4	Pallet 5	Pallet 6	Pallet 7	Pallet 8	Pallet 9	Pallet 10
Pallet 11	Pallet 12	Pallet 13	Pallet 14	Pallet 15	Pallet 16	Pallet 17	Pallet 18	Pallet 19	Pallet 20

Therefore the total weight of the pallets loaded is 3100kg (20*155). For the transportation, the weight will be the sum of the tare and the total weight of the goods, which is 10500kg. Based on the information provided, the carbon emission for one journey of transporting 20 pallets of 330 ml empty cans from Fosie to Stockholm will be 500 kg of CO_2. The calculated data and result is shown in the figure 25-27 and Appendix 11.

Figure 25. EcoTransIT application and parameter (EcoTransIt World, 2014).

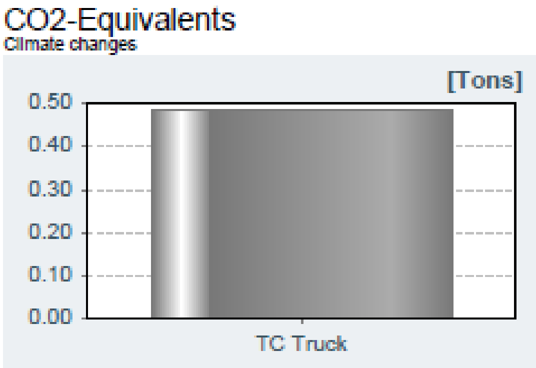

Figure 26. Carbon dioxide emission.

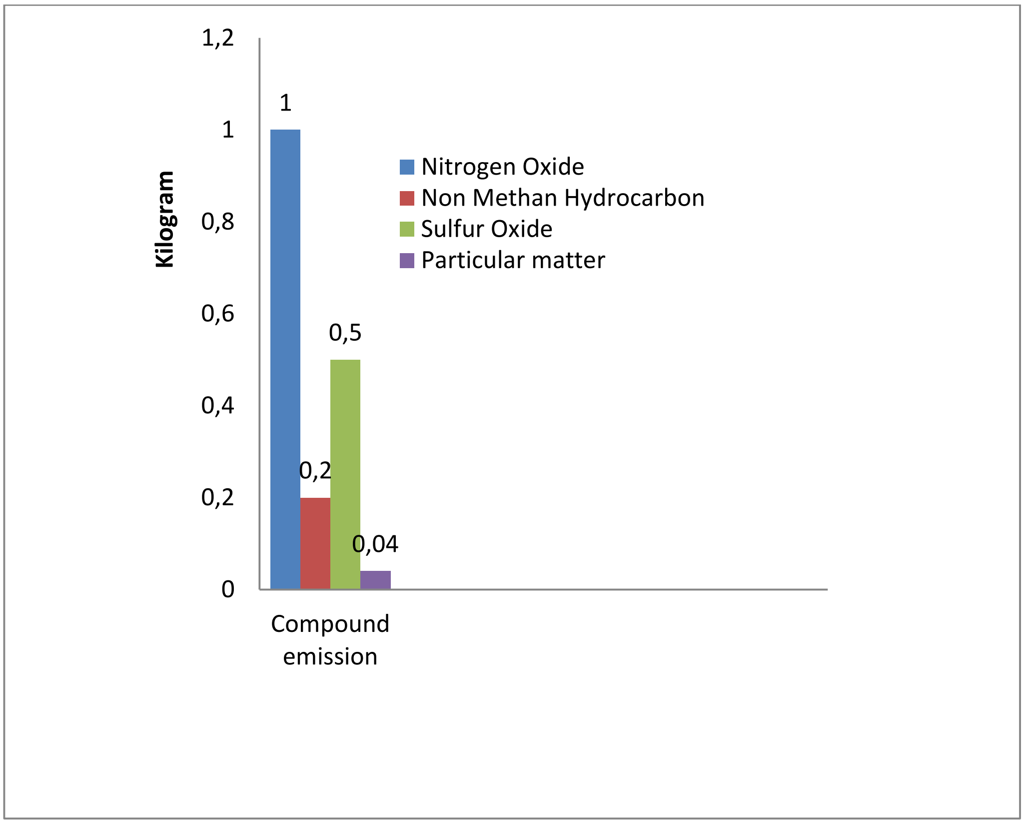

Figure 27. Scenario of 20 pallets 330ml empty can carbon emission.

3.3 Calculation of the carbon emission during empty can shipment (conical can)

The same scenario as created for the cylindrical can in section 3.2, was applied for the conical can. In order to calculate and compare the carbon emission generated during transportation. The number of cans per pallet was estimated using the data sheet from Huhtamaki Company (Huhtamaki, 2014) (appendix 10). The plastic cup, item no 86208 which is 12 Oz transparent plastic cup was used for the estimation. It is calculated that there will be 42000 cups per pallet (1000 cups per case). Based on the supposed alternative material of beverage can (Aluminum), which is unlike the material of the Huhtamaki cup (plastic). Aluminum is subtle to wear (Abrasive) and the surface quality is very important. Thus an assumed value of half of the Huhtamaki cup per pallet was suggested. Invariably, a total of 21000 cans per pallet were calculated, table 10 gives the details. Also, the printing on the aluminum can is another factor for selecting the value. Using the same weight of the cylindrical can and the weight of the pallet, it was estimated that a pallet will weigh 301kg. Also, the truck was calculated to accommodate 20 pallets. Finally, carbon emission for the same scenario created in section 2 was calculated. The figure 28 -30 and appendix 12 shows the values and emission.

Table 10. Calculation parameter.

CAN SIZE(conical)	330 ml
Total no of can per pallet	21000
No of pallet per journey	20
Total can per journey	420,000

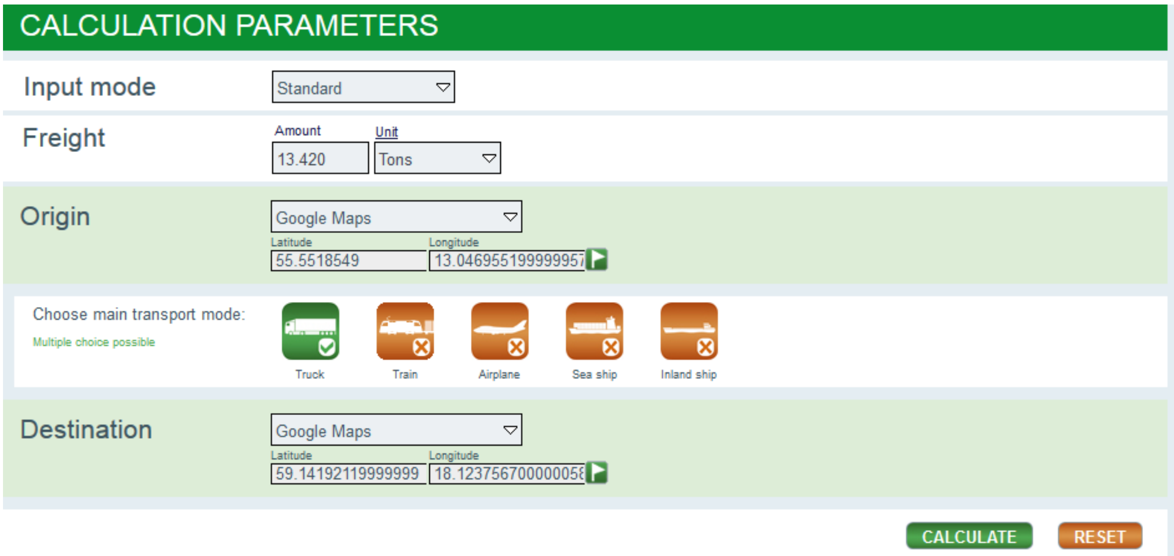

Figure 28. EcoTransIT application and parameter (EcoTransIt World, 2014).

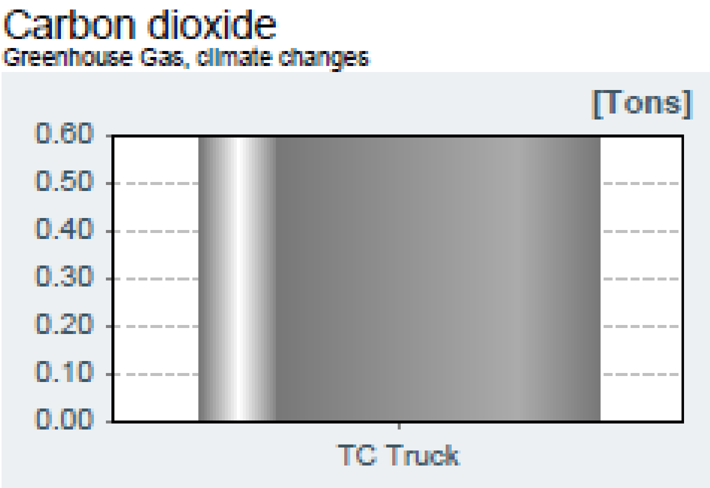

Figure 29. Carbon dioxide emission.

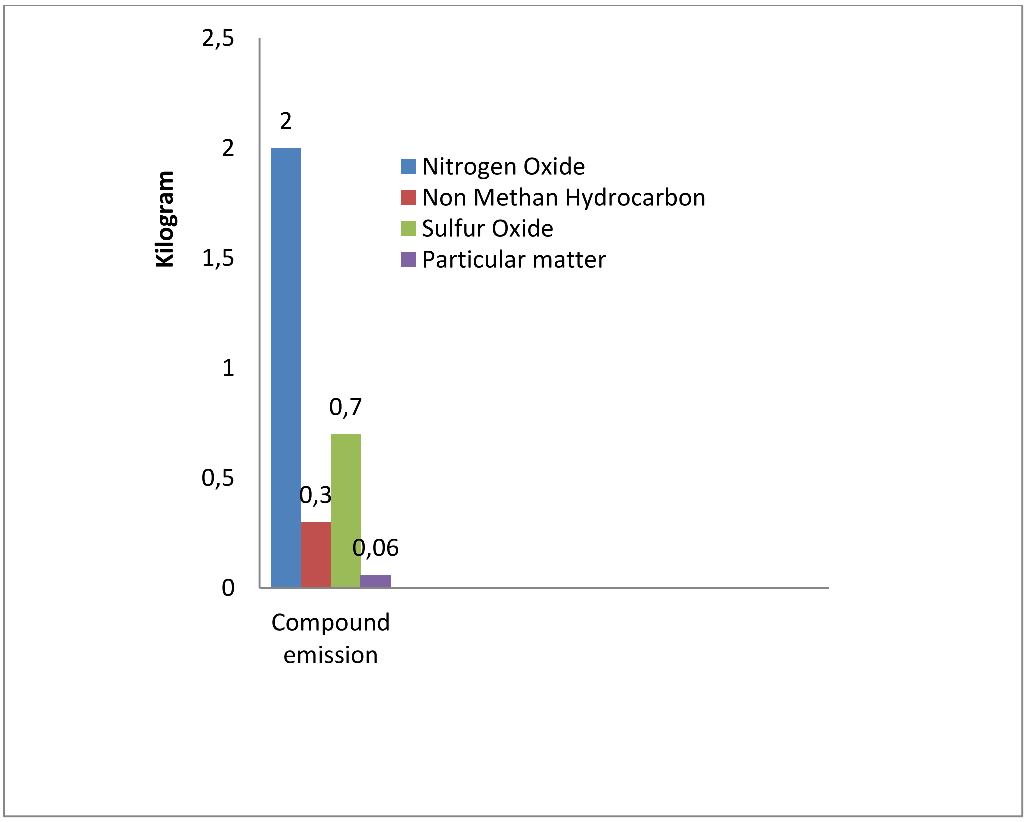

Figure 30. Conical can emission.

3.4 Scenario comparing between the Conical can and Cylindrical can

The amount of cylindrical cans and the quantity of supply (trip) to supply the same amount of conical cans for a single load supply was estimated. By finding total conical cans per journey ratio to total cylindrical cans per journey. The table 11 below shows the comparison.

Table 11. Calculation parameter.

	330 ml (cylindrical)	330 ml (conical)
Weight per pallet	155 kg	301 Kg
Total no of can per pallet	8602	21000
No of pallet per journey	20	20
Total can per journey	172,040	420,000

Conical can single journey equals 2.4 journey of the cylindrical can (420000: 172040 = 2.4). Then their emission is shown in figure 31-32 and appendix 13. The significance of these results are explained in the analysis section.

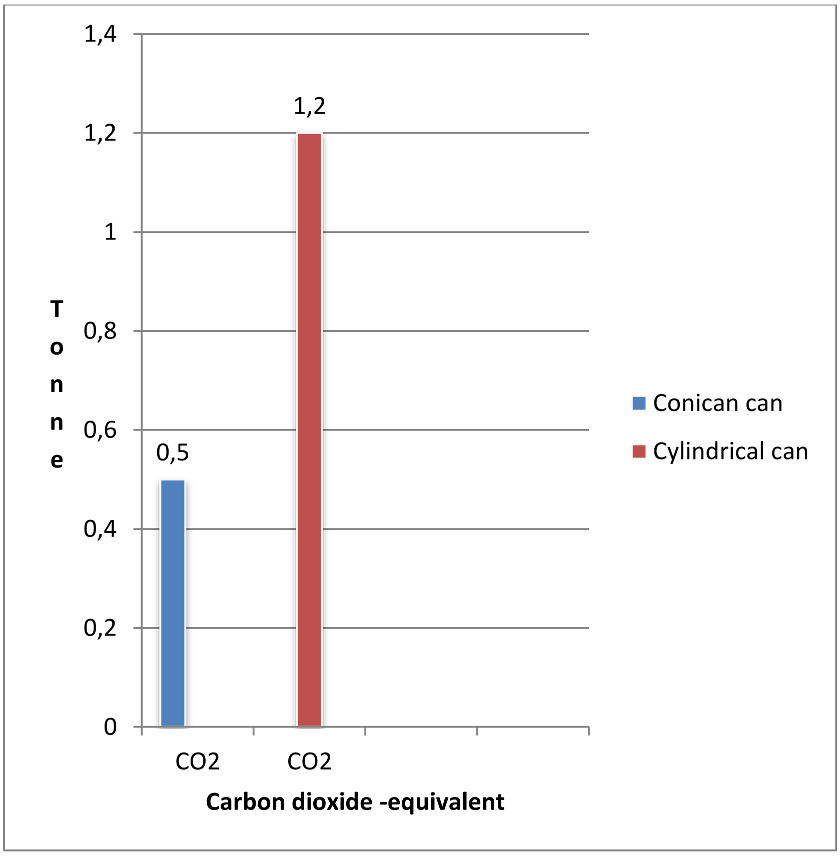

Figure 31. Carbon emission of the two designs.

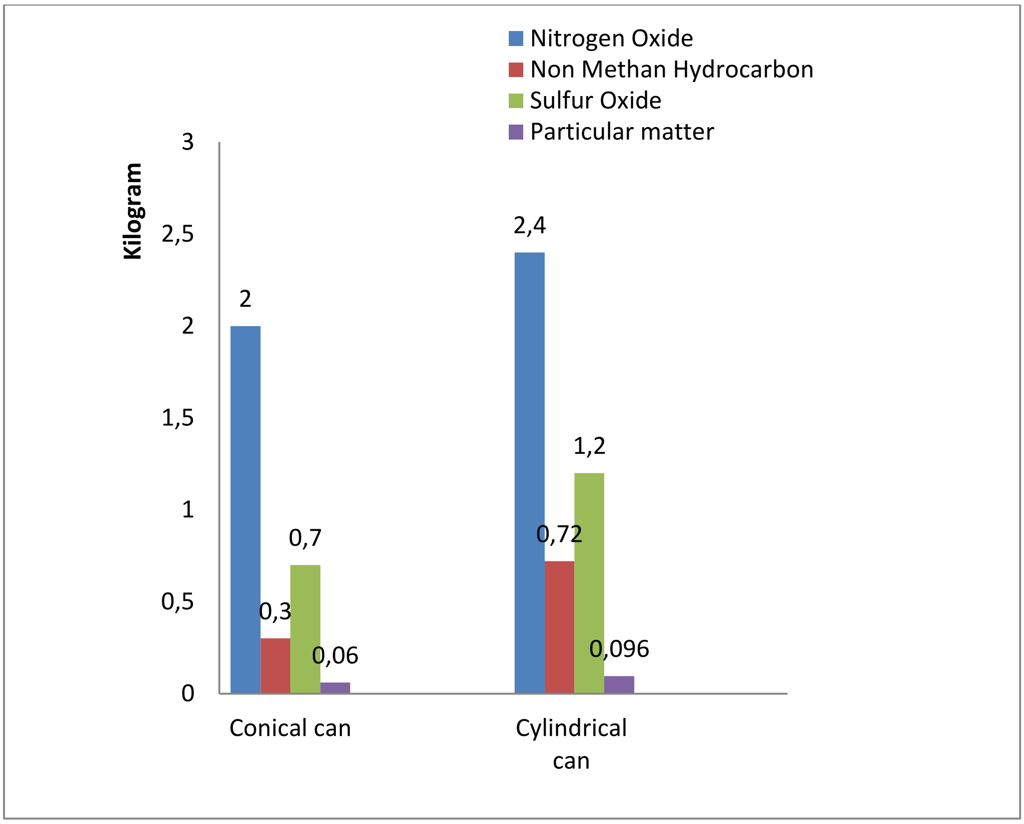

Figure 32. Emission of the two designs.

3.5 Result from the questionnaires

As stated, there are two questionnaire; questionnaire 1 for the consumer and questionnaire 2 for the industry. The results of the questionnaires are given in the following section. A total of 100 responses were received from the survey on questionnaire 1 and 1 response was received for questionnaire 2.

Questionnaire 1: for the consumer.

The objective of this questionnaire was to examine the consumer perception about the sustainability and the conical can. The survey was conducted from 7thDec, 2014 to 19th Dec, 2014. A total of hundred (n=100) responses were received. The results are shown in the graph below. The statistical tools such as Pearson correlation, mean and median etc. in Microsoft excel were used for the computation. The results are shown in figure 33-35.

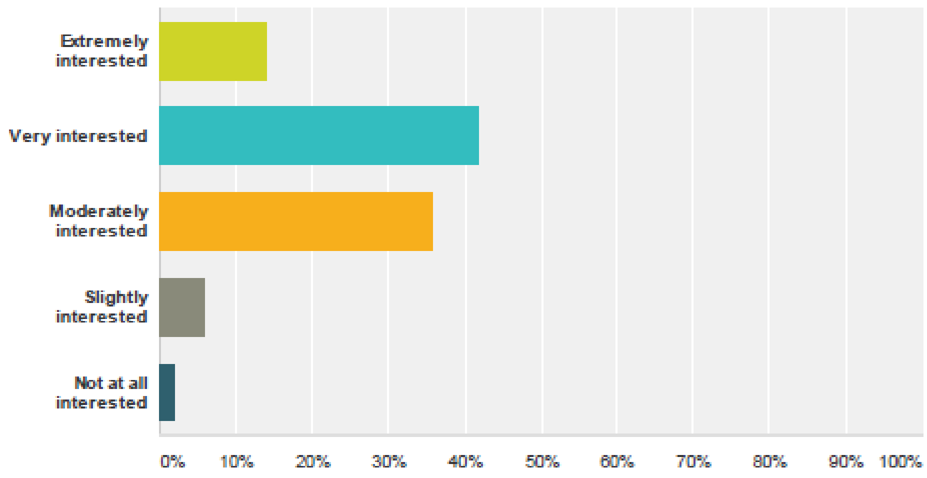

Figure 33. The Consumer interest in sustainability

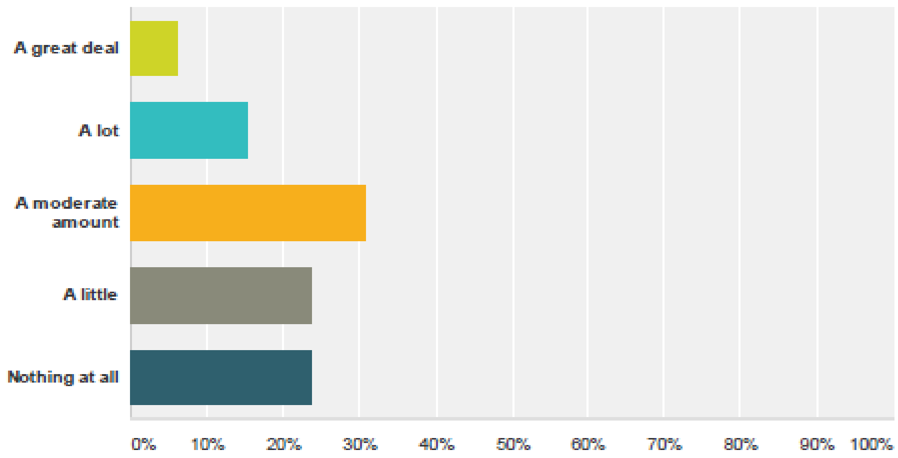

Figure 34. Consumer knowledge about Eco-label.

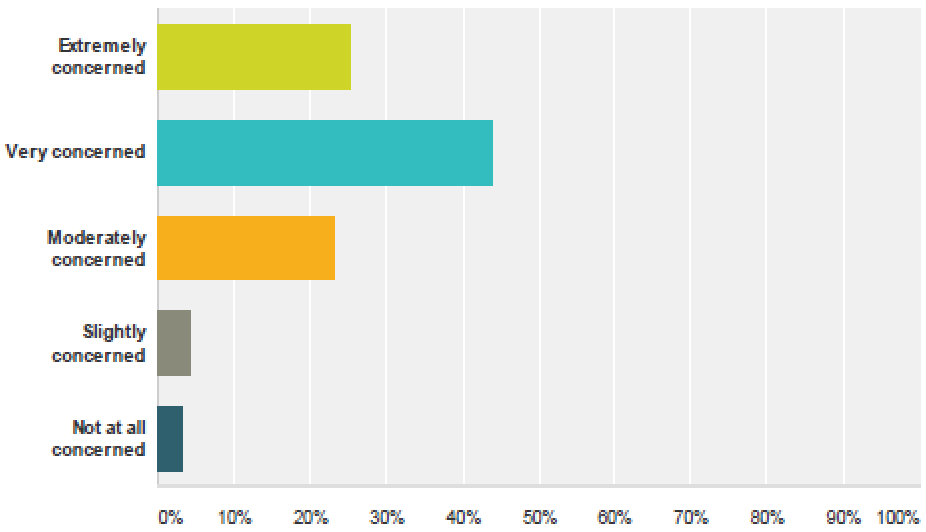

Figure 35.Consumer concerns about air pollution.

From the figures 33-35, it could be noted that there was a significant relationship between consumer concern about the air pollution and interest in sustainability, the Pearson correlation coefficient was used to measure the strength of the linear association of the two variables (Pripp, 2013, p. 22). The R value is 0.87. Also, the relationship between the consumer knowledge about Eco label and perception about sustainability was measured. The R value is 0.05. Although, with R>0.01, it means there might be no correlation but R equals to 0.05 could mean that consumers knowledge about Eco label might be limited. The facts that the rating of the knowledge measurement about Eco label is 2.56 (out of 5) support the notion that consumer are not aware about Eco label. The consumers' perception and rating about the conical can is given in figure 36-37.

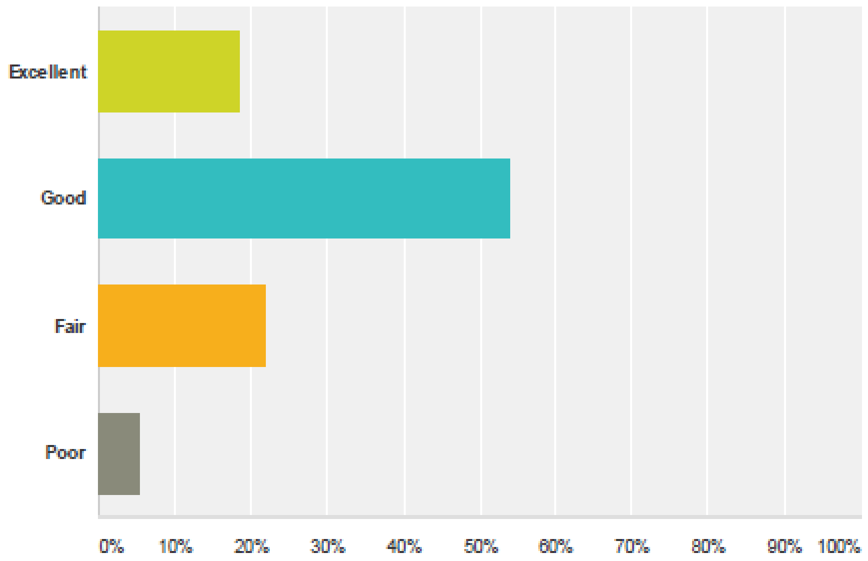

Figure 36. Consumers rating of the new design (conical shape).

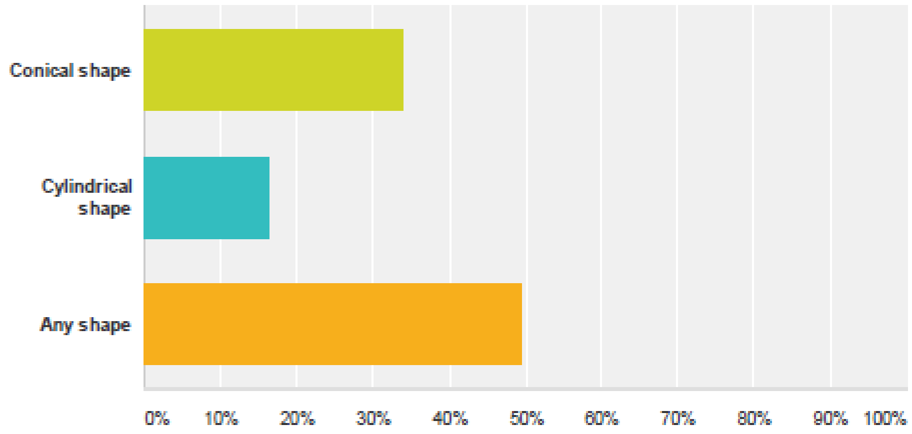

Figure 37.Consumers Preference for the shape of beverage can.

The rating of the consumer opinion of the conical can shape to the cylindrical can shape was 2.8 (out of 4), this means that it is considered as a good design when compared to the cylindrical can. This assumption was validated with their responses on the open end question, which asked about their opinion on the conical shape. Figure 37, shows the preferences of consumers among the conical shape, the cylindrical shape and if they are indifferent. The results show that 34.07% prefer the conical shape, 16.48% prefer the cylindrical shape while 49.45% will prefer any shape. This could establish that they consumers are slightly concerned about the shape of the beverage can.

The responses from open-end question in the questionnaire about the consumer opinion on sustainability were analysis by using some of the methods given in the open ended question analysis system and method (Pat. US4958284 A. 1988). 54 people responded to the question while 44 people skipped the question. The responses were reassigned to categories. The categories are the three main spheres of sustainability; The Environment, The Social and The Economy (Santoyo-Castelazo & Azapagic, 2014, p. 119). These categories are chosen to know what will be most important to the consumer among the three spheres of sustainability and the impact of the tribology to sustainable development (Tzanakis *et al.* 2012). The figure 38 represents the result.

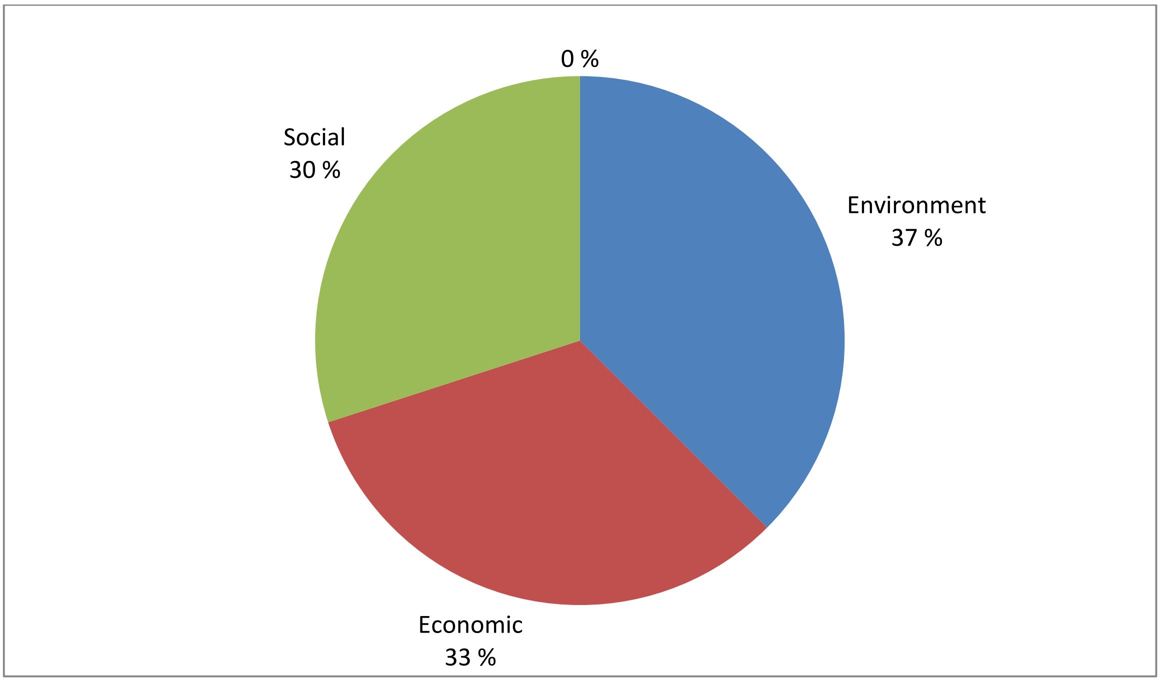

Figure 38. Customer interest and perspective about sustainability.

With the perception and opinion about sustainability spheres that are very close, it could be established that the participants are interested in various aspects of sustainability. For the responses concerning customer opinion about the conical can shape, 91 responses were achieved why 9 people skipped the question. Most respondents were related to the look of the package. The responses are summarized in the analysis section by explaining the potential benefits of the conical can to the consumer. There were 22 participants out of 100 participants who are willing to know more about this research.

Questionnaire 2: for the industry.

As stated the objective of this questionnaire was to specifically study the company perception about sustainability and the conical can. It was hoped that the result from the industry could be compared with the result from the consumer. Unfortunately, only one response was received from the industry. This single result could not be used to represent the direction or the objective of the industry. However, the response was slightly encouraging and could be summarized that there is a possibility of using the conical can if all challenges are managed and solved. Examples of the proposed design and the current design that the companies are using are shown is appendix 14 and appendix 15 respectively.

4 ANALYSIS

In this section, the results will be analyzed. The results were about the scenario calculation, the conical can design and the questionnaire. They are explained in sub-section below;

- The design
- The Scenario
- The questionnaires
- Benefits of the conical can shape (consumer perspective)
- Inter-relation of the results

4.1 The design

In finding the solution to the space optimization for the beverage can shipment, the conical can shape was suggested. A new 330 ml conical can was design using the solid work software. The body and the lid of the can were designed. The design was similar to some of the available plastic cups in the market. The major difference between the current cylindrical of 330 ml and the conical can of 330 ml was the height; the conical can was taller than the cylindrical can. However, their diameters were similar. This is to facilitate the usage of the current cylindrical can packing system (6-pack, crate) after filling for the conical can. Although the product was modeled using the solid works, nevertheless, more is needed for the mechanical simulation of the can. The in-depth analysis of the mechanical properties of the conical can was not done due to the scope of this research.

The look of the conical can after printing was acceptable and marketable; this conclusion was ascertained by the responses from the questionnaire. It was noted that various printing (labeling) option could be used for the conical can as the printing system has been established for the current can and the plastic cup. The conical can design was assumed to be a sustainable design because the principle of design for sustainability was used for it, thus it could be assumed as a sustainable product. (Jawahir, Badurdeen & Rouch , 2013, p. 12-15.) Thus if an aluminum material is used, then a sustainability label (eco label) could be received for it.

Reviewing the conical can whether it is a sustainable product, the six elements of product sustainability (Jawahir, Badurdeen & Rouch, 2013, p. 12-15.). The new design could be assumed to meet the requirement; however, the element yet to be proven is the manufacturability. The recyclability of the conical aluminum can has been proven by the study about the recyclability of aluminum by PE Americas (2010) and Liew (2005, p. 79).

4.2 The Scenario

According to the scenario, it was noted that further improvement could be achieved in design of the current beverage can to support the sustainability drive. As earlier stated, one of the EU plans for the present and the future is the drive toward a clean environment (EUROPEAN COMMISSION, 2010). The reduction in carbon emission is a part of the focus in achieving the objective. The scenario result provides the answer to one of the research question; can we have a more sustainable beverage can? The scenario expressly confirm that in relating to the three cores of sustainability; the economy, the social and the environment, redesign of the beverage can could offer results in those core areas.

The suggestion of the conical can as one of the options that could be implemented in the beverage industry is directly in line with the EU vision 2020. The scenario gives evidence about the space optimization of the beverage can. The conical aluminum can would achieve the intended space optimization during the empty can shipment. This is relating to the economical aspect of sustainability. The space optimization would lead to an increase in transports goods volume, thus reducing the numbers of journey and the amount of carbon emission that could have been generated (polluted). This result is directly related to the environmental aspect of sustainability. Also the introduction of the new design package (conical aluminum can) to the beverage industry tends to the social aspect of sustainability.

4.3 The Questionnaires

Two questionnaires were design and sent to the stakeholder, the analyses are written below.

Questionnaire 1: For the consumer.

According to the responses from the questionnaire 1, a significant relationship was noted between the consumer concern about air pollution and their interest in sustainability. The Pearson correlation coefficient was 0.89 and the P-Value is less than 0.00001 (P-value <0.00001). The result is significant at p less than 0.05 ($p < 0.05$); there is a significant positive correlation (Kremelberg, 2011, p.119). The Pearson correlation coefficient between consumer knowledge on Eco-label and sustainability was 0.05 and the P-Value is 0.62129. The result is *not* significant at $p < 0.10$; it means there is no significant relationship between them (Kremelberg, 2011, p.119). Also the rating of the responses about consumer knowledge on Eco-label was 2.56 (out of 5), which is between moderate and little knowledge about Eco-label. This might be an assertion that there is a need for more campaign about eco-label as this will boost the interest in sustainable consumption. However, the r value which is 0.05 and rating value which is 2.56 support that the consumer are aware that eco-label is related to sustainability and that eco-label might influence the consumer interest in buying a product. This research submission about sustainability, eco-label and air pollution could be seen as reliable as other researches as it proved that the sustainability consumption could influence what the consumer would buy. (Barreto *et al.,* 2014.)

With the rating value of 2.8 out of 4, where 4 represent excellent, the conical can package could be consider as a good design. Also, it proves that the consumer might buy the beverage packed in the conical can. Also, there is a likely social acceptance of the design if adopted by the beverage company. The results about the consumer-beverage can-shape preferences shows that 34.07% prefer the conical shape, 16.48% prefer the cylindrical shape while 49.45% will prefer any shape. The preference for the conical shape over the cylindrical shape established the fact that the consumer are interested in new design, they are concern about the sustainability rating of a product and that the conical shape has the possibility of social acceptance. Although the percentage of consumers which would prefer any shape is almost half of the population, this could buttress the result of little knowledge about eco-labeling and that many consumers are primarily not concerned about the package but the main product.

According to Figure 38, consumers are interested in all aspects of sustainability and they are most concerned about the environment aspect, this is in agreement with Barreto *et al.,* (2014). Also, the responses about the economic sphere of sustainability were mostly about the expensive nature of sustainability concept, that is, sustainable products are expensive.

However, the non-availability of sufficient responses from the industry limit what could be documented as the industry opinion on the conical can. The non-response could be assumed that they are not interested; however, this statement is not reliable as they could have communicated this opinion. Also the bureaucracy in the industry could be one of the reasons why the questionnaire was not answered.

4.4 Benefits of the conical can shape (consumer perspective)

Viewing the conical can from the consumer perspective, it was discussed that the conical can will not only be beneficial to the industry but also the consumer. The responses from the questionnaire and the interview highlighted the benefits of the conical can shape. The opinion was that the conical can will solve some challenges that are being experienced with the current cylindrical shape. Some of the benefits are discussed below.

Easy Handling of the product: Based on the shape of conical can, it was evident that the conical can will be easy to handle by the user/consumer. The cone shape provides a more secure to maintain a tight hold on the can easily by the consumer hand or holder, thus the can will be firmly seized. This could reduce ergonomically issues attributed to holding of can. Also, for the can holder in the car or other places, there will be no need to provide base support for the conical can as it was done for the cylindrical can, because the pressure on the side of the can will create equilibrium on the holder.

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No Rolling: One of the challenges faced by the cylindrical can is the rolling of the can whether filled or empty. The cylindrical shape of the can makes it easy to roll on any plane surface. The effect of this rolling is the extra stress for the consumer. Also, the rolling effect increases the littering of the can around. However, with the conical can, this issue is minimal, as the shape of the cone will hinder or obstruct the easy motion of the can after falling. Indirectly, the consumer intuition or feelings about the rolling of the can is reduced if not eliminated.

Disposal: The disposal of the package after usage is critical, a package should be easy to be disposed and return for recycling. Therefore, the after use of the package is important in the sustainability assessment of the product. A sustainable product should either be reusable, recyclable or re-design after fulfilling its primary function. It is assumed that further research about the top lid of the conical could suggest a lid that can easily be bent inward thereby creating the possibility of stacking the used-can into each other. The assumed results of easy disposal of the cans will further reduce the carbon emission, cost, space and time associated to the current disposal system.

Marketability and branding: The conical can being a new product has the tendency of increasing the sales. This was based on the acceptance of the product by the consumers based on the questionnaire. The conical can was attractive to the consumers. The benefits of easy handling and stability would likely make the consumer to go for the can if placed side by side with the cylindrical can.

Recyclability: The material suggested for the conical can was aluminum. Already aluminum in some perspective was considered to be a sustainable material based on its recyclability potential. The conical can will be easily recycled thereby, reducing the lifecycle cost. As Tabereaux (2014, p.839) stated that it the aluminum “recovery from scrap requires only 5% of the energy required to extract it from alumina”, thus making it a sustainable material.

Overall, the research problem was focused on the pre-usage of the conical shape and the result that could be achieved in the area of sustainability. However, based on the final proposed design and the responses from the consumer, it was discovered that the conical can shape of the can has many benefits to the consumers.

4.5 Inter-relation of the results

The main connection between the various results was the objective in achieving a sustainable product. The first scenario about the cylindrical can gives the opportunity for developing a new product to solve the space optimization problem. The outcome was the designing of a conical can. New scenarios that examine the conical can carbon emission during transportation support the idea that reduction in carbon emission is achievable. To understand the stakeholder perspective about the conical can and sustainable product, the questionnaire provides answer to it. The questionnaire’s result buttresses the need for sustainable packaging as consumers are concerned. Using the guide to effective packaging sustainability assessment (Australian Packaging Covenant, 2014, p.3), the results in this study was linked to the corporate sustainability goals and the impact of the sustainability tribology (Tzanakis *et al.,* 2012), this is shown in figure 39.

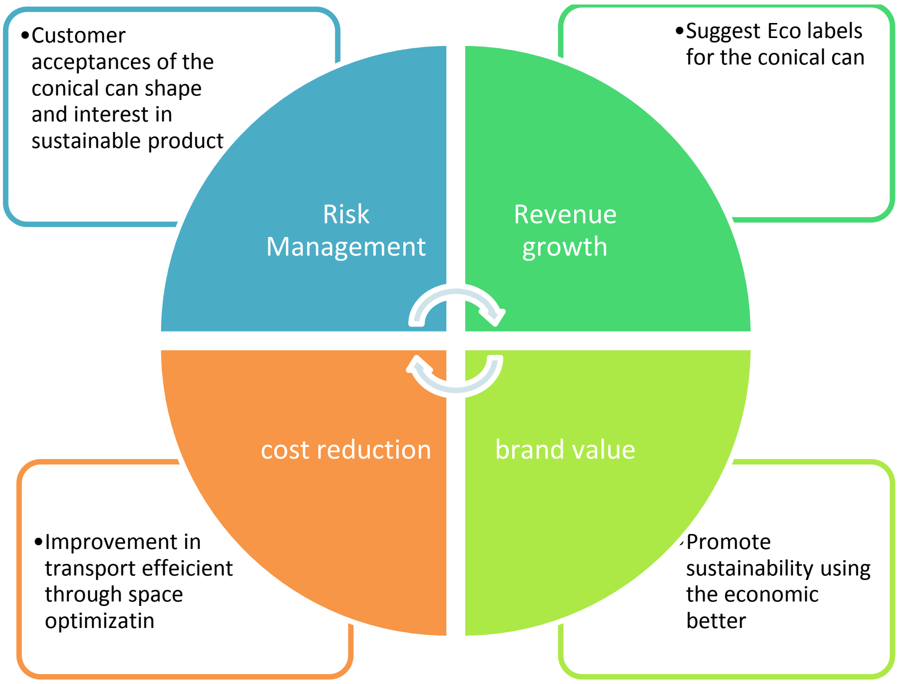

Figure 39. Linking of the research to corporate sustainability goals.

5 DISCUSSION

The purpose of this thesis was to study about the effect of carbon emission generated during the empty beverage can shipment. To research about the alternative way to reduce it, a new design was suggested, thus creating the name for this thesis; “Conical Aluminum Can”. The study concludes with a new shape of the beverage can as an option to achieve space optimization during shipment of the empty beverage can. This study gives suggestion about the reason for choosing the conical can over the cylindrical can. The evaluation relies on comparing the result of the conical and cylindrical can. This was established by comparison of the two. It begins with literature review about the beverage can, followed by designing of a new product, thereafter the scenario analysis. It was concluded with the questionnaire review.

From the scenario analysis, the possibility of reducing emission was possible if the conical can is used for the same logistics situation of the cylindrical can. The conical can will encourage space optimization during shipment. Thus, creating the possibility of reduction in the amount of emissions, logistic costs and transportation time. The result of the scenario comparing the conical can and the cylindrical can support the drive of the European Union toward reduction in emission in transport industry. This research has established that packaging can contribute to the emission reduction in the transportation sector.

From the survey, it was confirmed that the consumer are driving toward sustainable consumption (Lorek & Spangenberg, 2014), and that the sustainability rating of a product could influence the consumer perception about the product. However, it was noticed that there was little or no significant relationship between the population of consumer that are interested in sustainability and the eco-label, this establishes the need for more campaign and awareness about eco labels. The eco-label could help with the drive to sustainable consumption, thereby giving the eco-label product (sustainable product) an edge over others. Also, the result shows that the consumers are concerned about the air pollution as well as sustainability, which could be a result of many years of public awareness about sustainability. The high interest about sustainability could be a possibility that the EU Vision 2020 is achievable as the consumers are directly or indirectly a part of the sustainability stakeholders.

Another result from this study about the conical can shape was the acceptance by the consumer. The survey results shows that the consumer consider the design to be a good design. Their responses from the open-ended questions ascertain it. Their responses were summarized in the section about the benefits of the conical can shape to the consumer. The investigation about the consumer beverage shape preference, shows that almost half of the consumers (n=100) are not concerned about the shape of the beverage can, this could be rephrased that the some consumers are mostly concerned about the main product rather than the packages. However, with these results, there is a need for the packaging company to create a package that will add value to the consumer and the main product, one of the solution could be design of re-usable package.

The investigation about consumers opinion on sustainability suggest that the consumer are aware about sustainability mostly in the environment concept, this could be attributed to many campaigns and marketing occasions which have used the environment as their focus, this was evident as most of indices used by Böhringer & Jochem (2007) for measuring national sustainability are mostly focusing on the environmental spheres development. However, the result shows that consumers consider a sustainable product as an expensive product. Although, they are interested in sustainable consumption but the prices of sustainable product are assumed to be expensive. Thus, it is suggested in agreement with Lorek & Spangenberg (2014) that campaigns and enlightenments about sustainability should not only focus about the environment sphere but also the economy and social sphere. With proper campaign and marketing focusing on the economy sphere, this could lead to increase in demand for sustainable products.

The results from this study were positive and they reiterate the interest in further research about sustainable products. The interest and perception of consumer in sustainability and the conical can was established, they are interested in new and sustainable products. However, the lack of enough data from the questionnaires about the industry perspective, on sustainability and the conical can,which was as a result of the companies not responding to the survey could be assumed that they are likely not interested or they were limited by the company bureaucracy. In summary, the consumers are interested in conical can but the industry is not willing or ready for it. The information in this research support the notion that design for sustainability is an important tool for package design. It is in support of the EU vision 2020 and that packages has an important role in achieving the sustainable planet.

5.1 Limitation of the result

Although, the research was carried out in a university of technology using the scientific tools and methods, nevertheless, the non-availability of a can maker equipment and the testing laboratory limit the practicality of this research. However, the theoretical acceptability of the result of this research is based on the available data for the researcher which is primary and secondary data.

5.2 Future study

Due to the constraints of resources, the full details of the study about the conical can were not possible. It was suggested that further research will be required about the following;

- The in-depth FEM analysis of the conical can and the optimal design to support the mechanical properties requirement of the beverage can.
- The manufacturability of the conical can and the best method and parameters for the processes.

It is hoped that with further research, new results could be achieved which could add to the sustainability acceptance of the beverage can.

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Example of cylindrical can pallet assembly (REXAM).

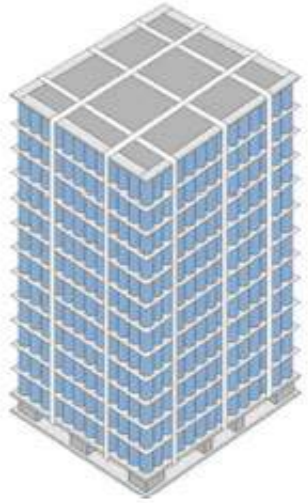
EXAMPLE OF CAN PALLET ASSEMBLY

Illustration shows four way entry pallet and timber top frame.

Banding illustration shows 3x2 but 2x2 is also used, depending on the pallet dimensions required.

Pallets of Cans are supplied in the format shown. The material used for pallets is plastic or wood and for top frames, plastic, wood or metal is used. The pallet size or height can vary, depending on the customers requirements.

External protection can also be provided if required by agreement in the form of stretchwrap.



STANDARD PALLETS FOR CANS

The number of layers can vary for each Can size. For confirmation of what is available, please contact your local Rexam office.

PLANT: FOSIE - Aluminium Cans

PALLET DIMENSION mm Length x Width	CAN SIZE ml	NUMBER OF LAYERS	CAN LAYER CONFIGURATION Length x Width (Number of Cans)	CANS PER LAYER	CANS PER PALLET	HEIGHT mm	NOMINAL WEIGHT, kg ALU	NOMINAL WEIGHT, kg STEEL	TOP FRAME MATERIAL	PALLET MATERIAL
1350x1200	330	22	23x17	391	8602	~2730	~155		Wood	Wood
SWEDISH	500	15	23x17	391	5865	~2710	~135			
1250x1180	330	23	18x20	360	8280	~2809	~155		Steel	Wood
GERMAN	500	16	18x20	360	5760	~2843	~135		Steel	Plastic
1420x1120	330	22	20x19	380	8360	~2700	~145		Wood	Wood
DUTCH/SPAIN	330	22	20x19	390	8580	~2700	~147		Steel	Wood
	500	15	20x19	380	5700	~2665	~135		Steel	Plastic
	500	15	20x19	390	5850	~2665	~137		Plastic	Plastic
1440x1120	330	18	21x19	399	7182	~2223	~130		Wood	Wood
ITALIAN	500	14	21x19	399	5586	~2497	~130			

PLANT: RECKLINGHAUSEN - Aluminium Cans

PALLET DIMENSION mm Length x Width	CAN SIZE ml	NUMBER OF LAYERS	CAN LAYER CONFIGURATION Length x Width (Number of Cans)	CANS PER LAYER	CANS PER PALLET	HEIGHT mm	NOMINAL WEIGHT, kg ALU	NOMINAL WEIGHT, kg STEEL	TOP FRAME MATERIAL	PALLET MATERIAL
1250x1180	250	19	22x25	550	10450	~2704	~150		Steel	Wood
GERMAN	330	23	18x20	360	8280	~2812	~155			Plastic
	355	17	18x20	360	6120	~2237	~125			
1420x1120	250	18	25x23	575	10350	~2597	~170		Wood	Wood
DUTCH/SPAIN	330	23	20x19	380	8740	~2839	~155		Steel	Plastic
	355	17	20x19	380	6640	~2264	~130		Plastic	
1300x1120	250	18	23x23	529	9522	~2596	~140		Plastic	Plastic
ENGLISH	330	22	18x19	342	7524	~2723	~140			
1350x1200 SWEDISH	330	22	19x20	380	8360	~2730	~150		Wood	Wood

PLANT: MANISA - Steel (330ml only) and Aluminium Cans (330ml and 500ml only)

PALLET DIMENSION mm Length x Width	CAN SIZE ml	NUMBER OF LAYERS	CAN LAYER CONFIGURATION Length x Width (Number of Cans)	CANS PER LAYER	CANS PER PALLET	HEIGHT mm	NOMINAL WEIGHT, kg ALU	NOMINAL WEIGHT, kg STEEL	TOP FRAME MATERIAL	PALLET MATERIAL
1420x1120	330	22	20x10+21x9	389	8558	~2723	~155	~280	Wood	Plastic
DUTCH/SPAIN	500	15	20x10+21x9	389	5835	~2702	~145		Plastic	Wood

Example of cylindrical can pallet assembly (REXAM).

PLANT: MILTON KEYNES - Aluminium Cans

PALLET DIMENSION mm Length x Width	CAN SIZE ml	NUMBER OF LAYERS	CAN LAYER CONFIGURATION Length x Width (Number of Cans)	CANS PER		NOMINAL			TOP FRAME MATERIAL	PALLET MATERIAL
				LAYER	PALLET	HEIGHT mm	WEIGHT, kg ALU	WEIGHT, kg STEEL		
1250x1180	440	15	18x20	360	5400	~2403	~128		Steel	Wood
GERMAN	500	15	18x20	360	5400	~2674	~135			Plastic
	568	13	18x20	360	4680	~2598	~130			
1420x1120	330	23	20x10+21x9	389	8947	~2839	~160		Wood	Wood
DUTCH/SPAIN	500	15	20x10+21x9	389	5835	~2702	~140		Plastic	Plastic
	568	11	20x10+21x9	389	4279	~2247	~120			
	440	17	20x10+21x9	389	6613	~2732	~145			
1300x1120	330	23	19x9+18x10	351	8073	~2839	~145		Plastic	Plastic
ENGLISH	440	17	19x9+18x10	351	5967	~2732	~135			
	440	18	19x9+18x10	351	6318	~2882	~140			
	500	15	19x9+18x10	351	5265	~2702	~130			
	500	16	19x9+18x10	351	5616	~2870	~136			
	568	13	19x9+18x10	351	4563	~2625	~125			
1350x1200	440	17	19x9+18x10	390	6630	~2738	~145		Wood	Wood
SWEDISH	568	11	19x9+18x10	390	4290	~2253	~120			

PLANT: WAKEFIELD - Aluminium Cans

PALLET DIMENSION mm Length x Width	CAN SIZE ml	NUMBER OF LAYERS	CAN LAYER CONFIGURATION Length x Width (Number of Cans)	CANS PER		NOMINAL			TOP FRAME MATERIAL	PALLET MATERIAL
				LAYER	PALLET	HEIGHT mm	WEIGHT, kg ALU	WEIGHT, kg STEEL		
1250x1180	330	22	18x20	360	7920	~2696	~145		Steel	Wood
GERMAN										Plastic
1420x1120	330	23	20x10+21x9	389	8947	~2839	~160		Steel	Wood
DUTCH/SPAIN									Plastic	Plastic
1300x1120	330	23	19x9+18x10	351	8073	~2839	~145		Plastic	Plastic
ENGLISH										
1350x1200	330	22	19x10+20x10	390	8580	~2730	~150		Wood	Wood
SWEDISH										

PLANT: EJPOVICE - Aluminium Cans

PALLET DIMENSION mm Length x Width	CAN SIZE ml	NUMBER OF LAYERS	CAN LAYER CONFIGURATION Length x Width (Number of Cans)	CANS PER		NOMINAL			TOP FRAME MATERIAL	PALLET MATERIAL
				LAYER	PALLET	HEIGHT mm	WEIGHT, kg ALU	WEIGHT, kg STEEL		
1350x1200	330	22	23x17	380	8740	~2730	~155		Wood	Wood
SWEDISH	500	16	23x17	380	6080	~2877	~140			
1250x1180	330	23	18x20	360	8280	~2826	~155		Steel	Wood
GERMAN	500	16	18x20	360	5760	~2857	~135		Wood	Plastic
	250	19	22x25	550	10450	~2718	~150			
1420x1120	330	23	20x19	380	8740	~2839	~155		Steel	Plastic
DUTCH/SPAIN	500	16	20x19	380	6080	~2871	~140		Wood	Wood
/ITALY	250	18	25x23	575	10350	~2596	~150		Plastic	
1300x1120	330	23	18x19	342	7866	~2839	~150		Plastic	Plastic
ENGLISH										

PLANT: DUNKERQUE - Steel Cans

PALLET DIMENSION mm Length x Width	CAN SIZE ml	NUMBER OF LAYERS	CAN LAYER CONFIGURATION Length x Width (Number of Cans)	CANS PER		NOMINAL			TOP FRAME MATERIAL	PALLET MATERIAL
				LAYER	PALLET	HEIGHT mm	WEIGHT, kg ALU	WEIGHT, kg STEEL		
1250x1180	330	23	18x20	360	8280	~2829		~270	Steel	Plastic
GERMAN	500	16	18x20	360	5760	~2870		~240		Wood
1420x1120	330	23	20x10+21x9	389	8947	~2839		~285	Steel	Wood
DUTCH/SPAIN	330	23	20x10+20x9	380	8740	~2839		~280	Plastic	Plastic
	500	15	20x10+21x9	389	5835	~2702		~240	Wood	
1300x1120	330	23	19x9+18x10	351	7722	~2839		~250	Plastic	Plastic
ENGLISH	500	15	19x9+18x10	351	5265	~2702		~220		

PLANT: BERLIN - Steel Cans

PALLET DIMENSION mm Length x Width	CAN SIZE ml	NUMBER OF LAYERS	CAN LAYER CONFIGURATION Length x Width (Number of Cans)	CANS PER		NOMINAL			TOP FRAME MATERIAL	PALLET MATERIAL
				LAYER	PALLET	HEIGHT mm	WEIGHT, kg ALU	WEIGHT, kg STEEL		
1250x1180	330	23	18x20	360	8280	~2826		~275	Steel	Plastic
GERMAN	500	16	18x20	360	5760	~2857		~244	Wood	Wood

APPENDIX 2

Manufacturing plant (Beverage Can Makers Europe, 2014).

MANUFACTURING PLANTS

Can Manufacturing Plants in Europe

Country	Can Manufacturer	Plant	No. of lines	Material
Austria	Rexam	Enzesfeld	3	A
	Rexam	Ludesch	4	A
Czech Republic	Rexam	Ejpovice	1	A
Denmark	Rexam	Fredericia	2	A
Finland	Rexam	Mäntsälä	1	A
	Can-Pack*	Hämeenlinna	1	A
France	Ball Packaging Europe	Bierne	3	S
	Ball Packaging Europe	La Ciotat	2	A
	Crown Bevcan EMEA	Custines	3	S
Germany	Ball Packaging Europe	Weissenthurm	3	S
	Ball Packaging Europe	Hassloch	2	A
	Ball Packaging Europe	Hermsdorf	2	A
	Rexam	Berlin	3	A
	Rexam	Gelsenkirchen	3	A
	Rexam	Recklinghausen	3	A
Greece	Crown Bevcan EMEA	Patras	2	A
	Crown Bevcan EMEA	Corinth	2	A
Italy	Rexam	Nogara	2	A
	Rexam	San Martino	1	A
Netherlands	Ball Packaging Europe	Oss	2	A
Poland	Ball Packaging Europe	Radomsko	2	A
	Bagpack*	Stalowa Wola	1	S
	Can-Pack*	Brzesko	4	A
	Can-Pack*	Bydgoszcz	2	A
Romania	Can-Pack*	Bucharest	1	A
Russia	Rexam	Naro-Fominsk	4	A
	Rexam	Vsevolozhsk	2	A
	Rexam	Argayash	1	A
	Can-Pack*	Volokolamsk	1	A
	Can-Pack*	Novocherkassk	1	A
Serbia	Ball Packaging Europe	Belgrade	2	A
Slovakia	Crown Bevcan EMEA	Kechnec	2	A
Spain	Crown Bevcan EMEA	Agoncillo	3	S
	Crown Bevcan EMEA	Seville	2	S
	Rexam	Valdemorillo	3	S
	Rexam	La Selva	3/1	S/A
Sweden	Rexam	Malmö	4	A
Turkey	Crown Bevcan EMEA	Izmit	2	A
	Crown Bevcan EMEA	Osmaniye	1	A
	Rexam	Manisa	2	A
UK	Ball Packaging Europe	Wrexham	4	A
	Ball Packaging Europe	Rugby	2	S
	Can-Pack*	Scunthorpe	2	A
	Crown Bevcan EMEA	Leicester	2	A
	Crown Bevcan EMEA	Carlisle	5	A
	Rexam	Milton Keynes	3	A
	Rexam	Wakefield	3	A
Ukraine	Can-Pack*	Kiev	1	A

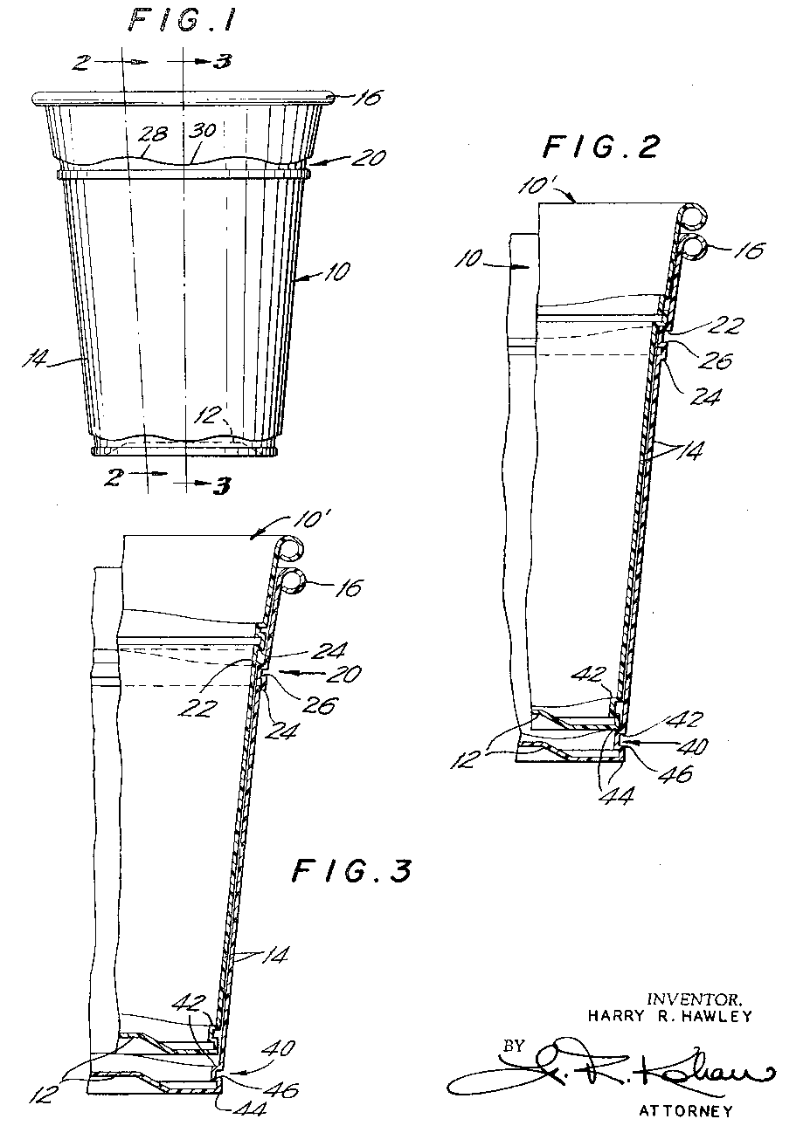
Information correct as of 30 July 2014 — * Not members of BCME — A - Aluminium S - Steel

Cup stacking means (Pat. US 3519165A, 1970).

July 7, 1970 H. R. HAWLEY 3,519,165

CUP STACKING MEANS

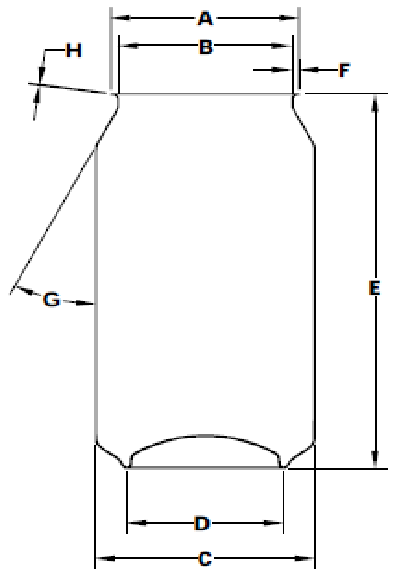
Filed March 17, 1969



The cylindrical data (REXAM, 2014).

REXAM Beverage Cans Europe & Asia

PRODUCT DATA SHEET



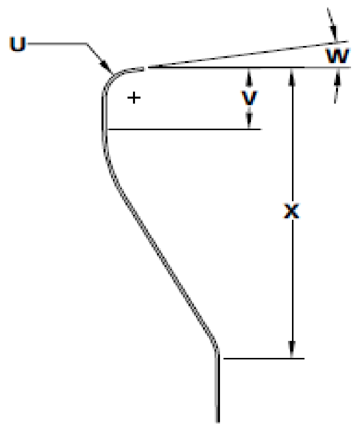
PRODUCT DESCRIPTION

57x66 (206/211)
330ML ALUMINIUM 206 NECK
202 BASE - PAf

ALL DIMENSIONS ARE IN MILLIMETRES AND ARE REFERENCE UNLESS STATED OTHERWISE.

A	Flange Diameter	62.5 MAX
B	Plug Diameter	57.40 +/- 0.30
C	Body Diameter	66.3 MAX
D	Stand Diameter	47.29 REF
E	Open Can Height	115.20 +/- 0.30
F	Flange Width	2.20 +/- 0.25
G	Neck Angle	29.5°
U	Flange Radius	1.52 REF
V	Neck Seaming Clearance	3.0 MIN
W	Flange Angle	0 - 12°
X	Shoulder Height	13.7 REF
H	Flange Thickness *(To be used in Seam Calculations)*	0.180

- Freeboard — 12.2 MM NOMINAL
- Inside Lacquer — MODIFIED EPOXY



REXAM BEVERAGE CAN Europe & Asia
Maryland Road
Tongwell
Milton Keynes MK15 8HF
Tel: 00 44 (0) 1908 517600
Fax: 00 44 (0) 1908 517628

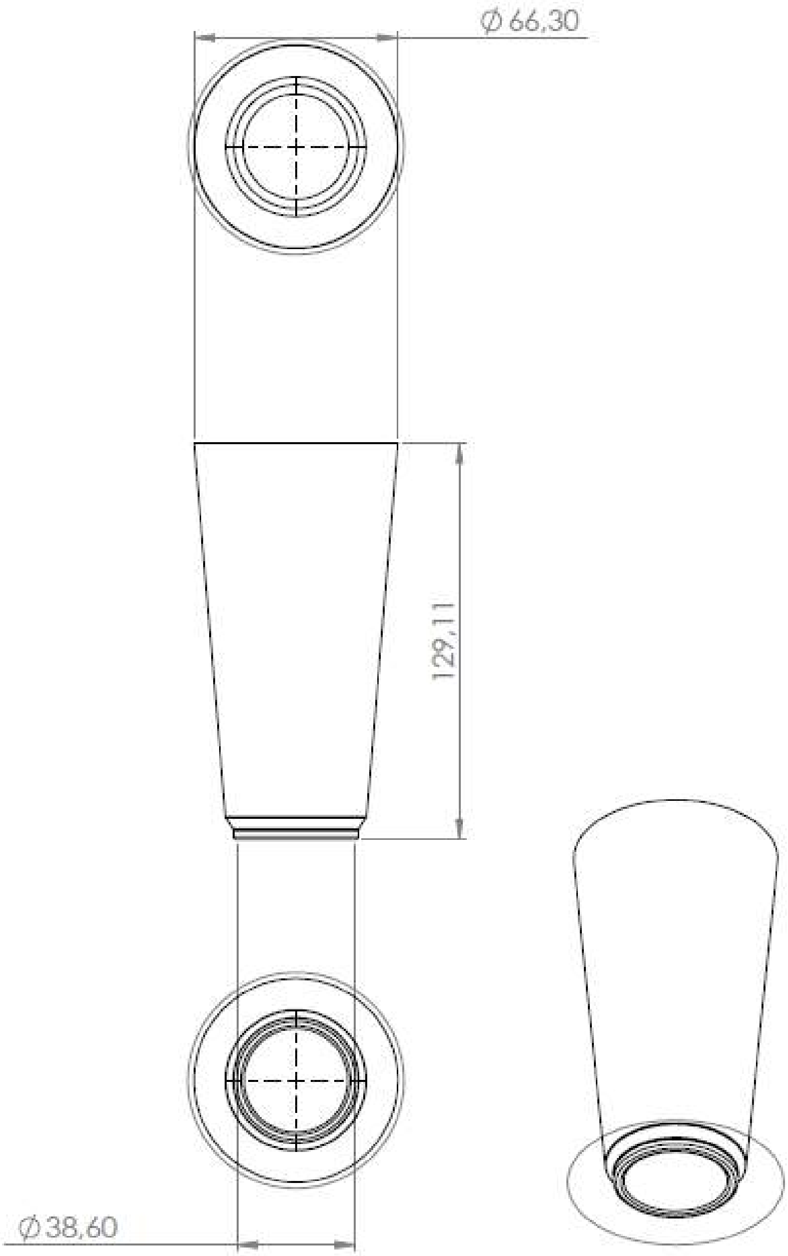
Manufacturing Plants: FOSC, REKC, EJPO NARC

RQP43 Form 1 (Revision 0 Page 1 of 1

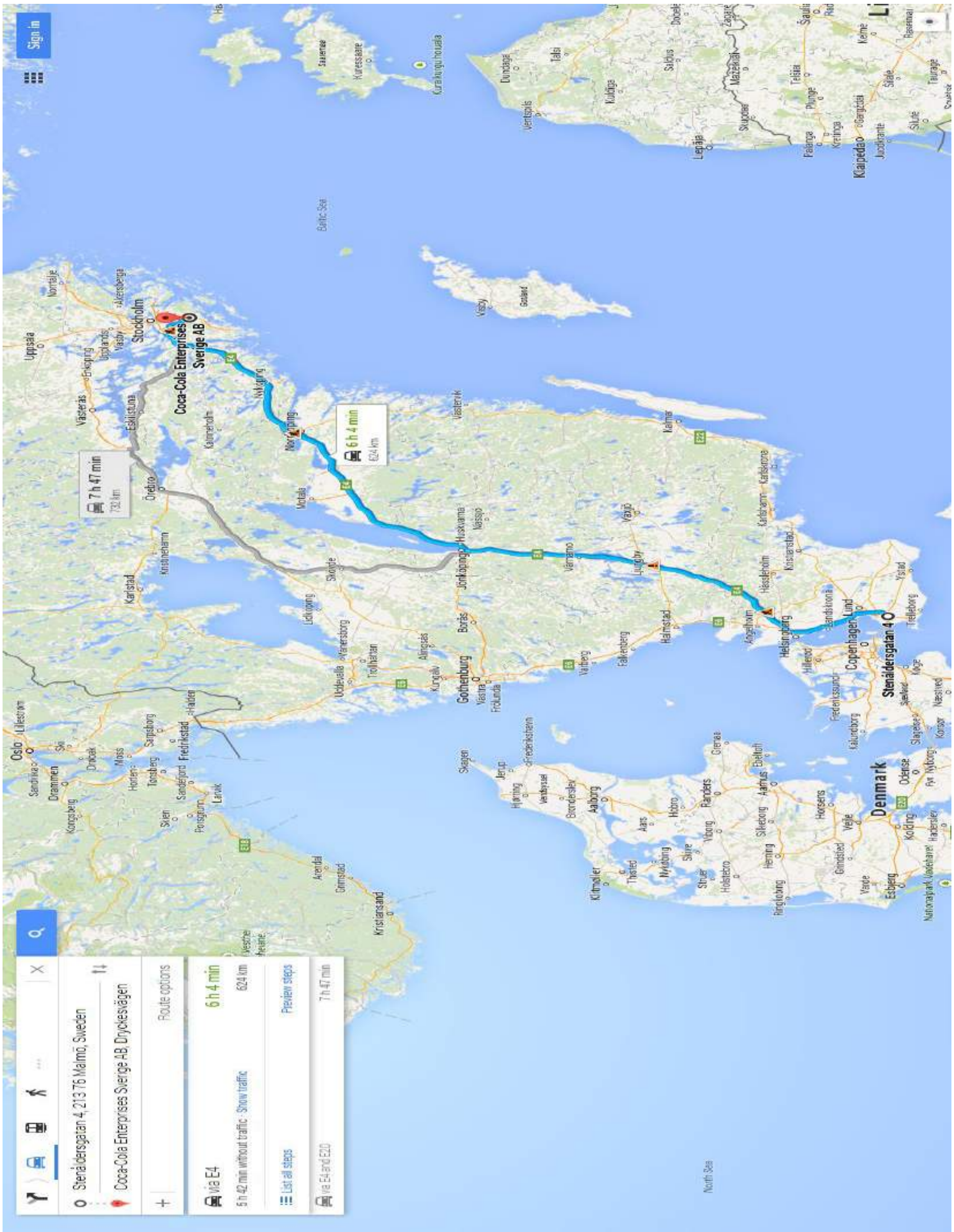
Approved By:
Quality Director

PDS Number:	Revision.	Date.
C122	10	16/02/05

Conical can.



Map of the scenario.



Questionnaire 1: For the consumer.

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FOR THE CONSUMER: THE CONI. Summary Design Survey Collect Responses Analyze Results

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- Matrix of Dropdown Menus Upgrade
- Ranking
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- Multiple Textboxes
- Comment Box
- Contact Information
- Date / Time
- Text

QUESTION BANK

LOGIC

OPTIONS

THEMES

Deleted Questions (20)

PAGE 1 Page Logic Copy Move Delete P1: Welcome to ...

Page Title

Welcome to My Survey

You're good up to 100 characters.

Page Description

The current beverage cans (Cylindrical cans) are stacked on each other after production, thus consuming a lot of space. Indirectly, this could result to high carbon emission during transportation. The problem is how to minimize the carbon emission based

Save Cancel

Confidentiality: The response will be treated as confidential and responses compiled and analyzed as group.

Thank you for participating in our survey. Your feedback is important.

Seyi Emmanuel Oyajumo
Department of Mechanical Engineering,
School of Technology,
Lappeenranta University of Technology (LUT) P.O. BOX 20,
FIN-53851 LAPPEENRANTA,
FINLAND.

seyi.oyajumo@lut.fi

Questionnaire 1: For the consumer.

Next

+ Add New Page

PAGE 2 Page Logic Copy Move Delete P2: Section 1: In...

Section 1: Investigating the beverage can's stakeholder perception about sustainability

The research is about the possibility of introducing the conical can shape as an option for space optimization during transportation of empty can and reduction of the carbon emission related to empty can transportation.

LUT
Lappeenranta
University of Technology

Questionnaire 1: For the consumer.

*** 1. What is your interest in sustainability?**

Extremely interested

Very interested

Moderately interested

Slightly interested

Not at all interested

2. How much do you know about ecolabel?

A great deal

A lot

A moderate amount

A little

Nothing at all

3. What is your opinion on sustainable product?

Prev Next

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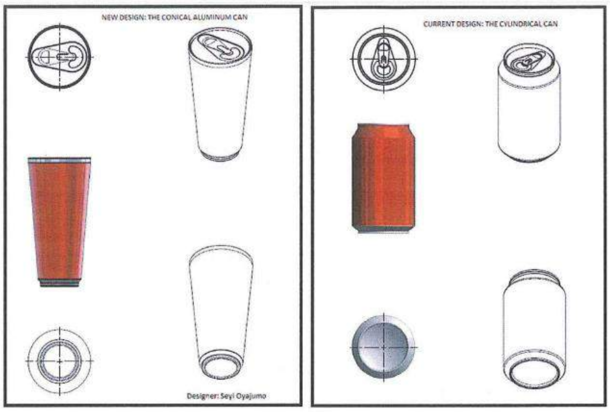
+ Add New Page

PAGE 3 Page Logic Copy Move Delete P3: Section 2:Inv...

Section 2:Investigating the stakeholder perception about the conical can

Kindly check the picture.

Questionnaire 1: For the consumer.



*** 4. How concerned are you about air pollution?**

Extremely concerned

Very concerned

Moderately concerned

Slightly concerned

Not at all concerned

*** 5. How will you rate the conical can (new design) to the current cylindrical can?**

Excellent

Good

Fair

Poor

*** 6. What shape of the beverage can will you prefer?**

Conical shape

Cylindrical shape

Any shape

*** 7. What is your opinion on the conical can shape?**

8. Are you willing to know more about this research? If yes,

Email Address

Questionnaire 1: For the consumer.

Prev Done

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Questionnaire 2: For the Industry.

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FOR THE INDUSTRY: THE CONICA Summary | Design Survey | Collect Responses | Analyze Results

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BUILDER

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- Matrix / Rating Scale
- Matrix of Dropdown Menus (Upgrade)
- Ranking
- Net Promoter® Score
- Single Textbox
- Multiple Textboxes
- Comment Box
- Contact Information
- Date / Time
- Text

QUESTION BANK

LOGIC

OPTIONS

THEMES

Deleted Questions (9)

PAGE 1 Page Logic Copy Move Delete P1: Introduction

Page Title

Introduction

You're good up to 100 characters.

Page Description

The current research on "beverage can" has mostly been toward reducing the thickness, less has been considered in the area of space optimization of the product after production. The current beverage (cylindrical shape) cans are stacked on each other after

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transportation. They will be stacked inside each other before filling and after usage.

The research is about the possibility of introducing the conical can shape as an option of space optimization during transportation of empty cans and reducing the carbon emission related to empty "can" transportation. Thus, creating a more sustainable beverage can. A diagram of the proposed beverage can shape is shown in this questionaire.

Confidentiality: The response will be treated as confidential and responses compiled and analyzed as group.

Thank you for participating in our survey. Your feedback is important.

Seyi Emmanuel Oyajumo
Department of Mechanical Engineering,
School of Technology,
Lappeenranta University of Technology (LUT) P.O. BOX 20,

Questionnaire 2: For the Industry.

FIN-53851 LAPPEENRANTA,
FINLAND.
seyi.oyajumo@lut.fi

Next

+ Add New Page

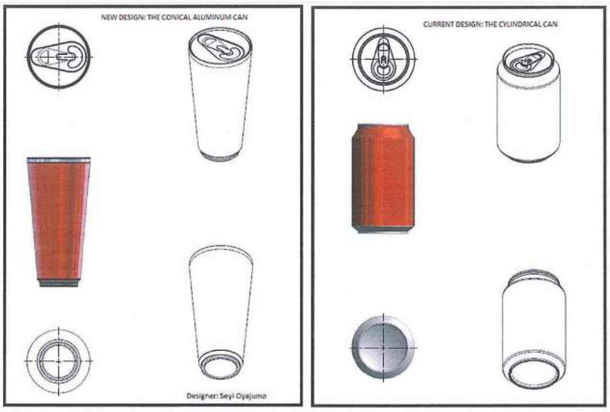
PAGE 2 Page Logic Copy Move Delete P2: Finding perc...

Finding perceived obstacles to the introduction of the sustainable conical can.

The research is about the possibility of introducing the conical can shape as an option of space optimization during transportation of empty can and reducing the carbon emission related to empty can transportation. Thus, creating a more sustainable beverage can. A Picture of an example of the can is shown below.

LUT
Lappeenranta
University of Technology

Questionnaire 2: For the Industry.



*** 1. What's your first reaction to this Conical can design idea?**

Very positive

Somewhat positive

Neutral

Somewhat negative

Very negative

*** 2. How important is sustainability to your company?**

Extremely important

Very important

Moderately important

Slightly important

Not at all important

3. How likely will your company use the conical can?

Extremely likely

Quite likely

Moderately likely

Slightly likely

Not at all likely

Questionnaire 2: For the Industry.

4. Has your company introduced a new product or design within the last five year?

YES

NO

Other (please specify)

5. Do you have the capacity to introduce (manufacture or use) the conical can?

Yes

No

Other (please specify)

*** 6. What could be the obstacles of introducing the Conical Aluminum Can?**

7. Would you be willing to participate in a short follow up interview?
If yes, your email:

Email Address

8. I will be interested in receiving the results of this study?
If yes, your email:

Email Address

Prev Done

+ Add New Page

Truck dimension (ABIPA, 2012).

UNIT HELLAS GROUP
INTERNATIONAL FORWARDERS

Truck dimensions

Type	Dimensions/Capacity	
Euroliners These curtainsiders feature a sliding roof, sliding curtains, solid rear doors, 32 side boards and side gates. They allow for quick easy loading and discharges via the rear doors and open side access. Side posts can be moved from side to side to facilitate loading. Suitable for multi-collection and multi-delivery shipment.	Overall length	13.7m
	Overall width	2.6m
	Overall height	4m
	Internal length	13.62m
	Internal width	2.48m
	Internal height	2.65m front, 2.75m rear
	Tare	6,880 – 7,100kg
	Design gross weight	39,000 – 41,000kg
	Capacity	33 Euro pallets/26 UK standard pallets 87m^3
Mega (High Cube) trailers Our Mega curtainsiders feature a massive 100m^3 capacity. The larger internal height enables shippers to maximise consignment size whilst having the benefits of a straight frame loading bed. All trailers have easy loading and discharge via open side and rear door access including sliding and lifting roof. They are also equipped with 32 side boards.	Overall length	13.7m
	Overall width	2.6m
	Overall height	4m
	Internal length	13.62m
	Internal width	2.48m
	Internal height	3.0m
	Tare	7,400kg
	Design gross weight	39,000kg
	Capacity	33 Euro pallets/26 UK standard pallets 100m^3
Mesh trailers Mesh trailers are the same as our Euroliners with the difference that these trailers are equipped with strengthened tilts by the use of metal weaving in the tilts. These are used for the transportation of high value goods.	Overall length	13.7m
	Overall width	2.6m
	Overall height	4m
	Internal length	13.62m
	Internal width	2.48m
	Internal height	2.65m front, 2.75m rear
	Tare	7,100kg
	Design gross weight	41,000kg
	Capacity	33 Euro pallets/26 UK standard pallets 87m^3

Huhtamaki cups (Huhtamaki,2014).

Translucent CUPS

Sizes **RANGE** from
5 OZ to **16 OZ**

Fits **DRINKS** *and* **BUDGETS**

Cup design *adds* **STRENGTH**

Cups

Item Number	Item Description	Case Dimensions Length	Width	Height	Case Pack	Inner Pack (bags/pieces)	Case Cube	Case Weight (lbs)	Pallet TiHi
82614	5 oz. Trans Plastic Cup	22.83	14.96	14.96	2500	(25/100)	2.96	20.4	7 x 4
86201	7 oz. Trans Plastic Cup	18.63	12.13	19.56	2500	(25/100)	2.56	23.0	7 x 4
86202	9 oz. Trans Plastic Cup	19.63	12.81	21.56	2500	(25/100)	3.14	25.8	7 x 4
86203	10 oz. Trans Plastic Cup	12.00	10.00	20.63	1000	(10/100)	1.43	14.9	16 x 4
86208	12 oz. Trans Plastic Cup	18.38	14.81	13.38	1000	(20/50)	2.11	18.0	6 x 7
86209	14 oz. Trans Plastic Cup	15.81	19.63	15.88	1000	(20/50)	2.85	16.5	6 x 6
86206	16 oz. Trans Plastic Cup	14.06	11.81	20.63	1000	(20/50)	2.26	20.0	6 x 7

Lids

Item Number	Item Description	Case Dimensions Length	Width	Height	Case Pack	Inner Pack (bags/pieces)	Case Cube	Case Weight (lbs)	Pallet TiHi
89151	12 oz. Trans Plastic Lid	18.56	7.81	18.12	1000	(10/100)	1.52	5.1	10 x 6
89152	14 oz. Trans Plastic Lid	20.94	8.56	20.63	1000	(10/100)	2.14	5.8	10 x 4
89153	16 oz. Trans Plastic Lid	19.31	8.06	19.62	1000	(10/100)	1.76	5.8	12 x 5

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Result of Cylindrical Can (1).

EcoTransIT - Ecological Transport Information Tool

The Ecological Transport Information Tool (EcoTransIT) calculates and compares the environmental impacts of goods transported by different modes. EcoTransIT compares the energy consumption, greenhouse gas and exhaust emissions of freight transported by rail, road, ship and aircraft.

Calculation parameter

Creation Date:	10.11.2014
Origin:	55.5518549 / 13.046955199999957
Destination:	59.14192119999999 / 18.123756700000058
Cargo weight:	10.5 ton (t/TEU: 10.5)
Input mode:	Standard

Transport Chain Road - 632,59 km

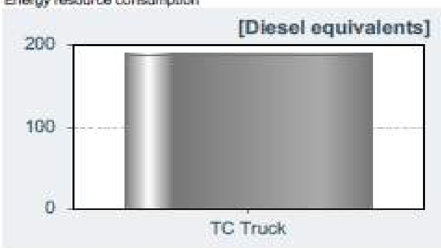
Origin: 55.5518549 / 13.046955199999957

Road (26-40 t, EURO-V, Load factor:60.0%, ETF:20%, Ferry routing normal)

Destination: 59.14192119999999 / 18.123756700000058

Result of Cylindrical Can (2).

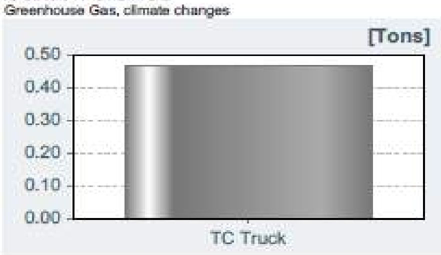
Primary energy consumption
Energy resource consumption



[Diesel equivalents]

	TC Truck
Truck	189
Sum	189

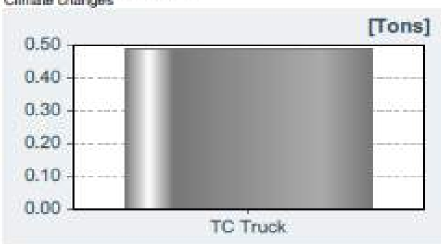
Carbon dioxide
Greenhouse Gas, climate changes



[Tons]

	TC Truck
Truck	0,5
Sum	0,5

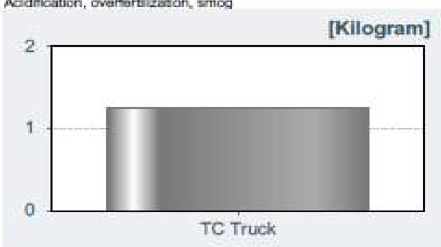
CO2-Equivalents
Climate changes



[Tons]

	TC Truck
Truck	0,5
Sum	0,5

Nitrogen oxides
Acidification, overfertilization, smog



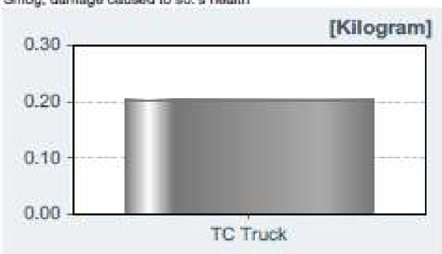
[Kilogram]

	TC Truck
Truck	1
Sum	1

Result of Cylindrical Can (3).

Nonmethane hydrocarbon

Smog, damage caused to so.'s health

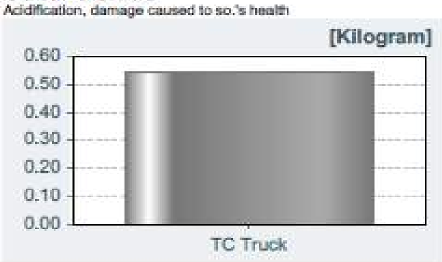


[Kilogram]

	TC Truck
Truck	0,2
Sum	0,2

Sulfur dioxide

Acidification, damage caused to so.'s health

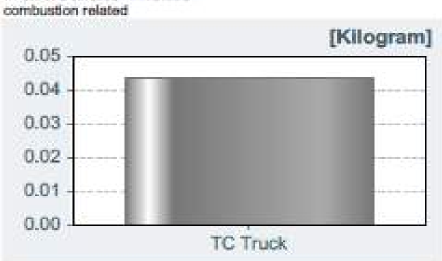


[Kilogram]

	TC Truck
Truck	0,5
Sum	0,5

Particulate matter

combustion related

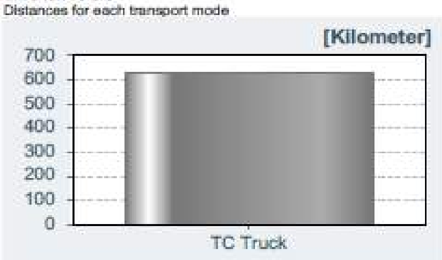


[Kilogram]

	TC Truck
Truck	0,04
Sum	0,04

Distances

Distances for each transport mode



[Kilometer]

	TC Truck
Truck	633
Sum	633

Result of carbon emission of conical can scenario (1).

EcoTransIT - Ecological Transport Information Tool

The Ecological Transport Information Tool (EcoTransIT) calculates and compares the environmental impacts of goods transported by different modes. EcoTransIT compares the energy consumption, greenhouse gas and exhaust emissions of freight transported by rail, road, ship and aircraft.

Calculation parameter	
Creation Date:	10.11.2014
Origin:	55.5518549 / 13.046955199999957
Destination:	59.14192119999999 / 18.123756700000058
Cargo weight:	13.42 ton (t/TEU: 10.5)
Input mode:	Standard

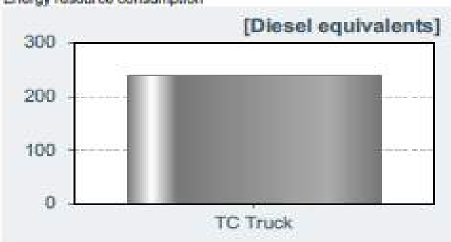
Transport Chain Road - 632,59 km	
Origin:	55.5518549 / 13.046955199999957
	Road (26-40 t, EURO-V, Load factor:60.0%, ETF:20%, Ferry routing normal)
Destination:	59.14192119999999 / 18.123756700000058

Result of carbon emission of conical can scenario (2).

EcoTransIT World

Primary energy consumption

Energy resource consumption

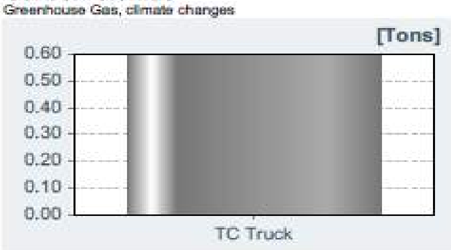


[Diesel equivalents]

	TC Truck
Truck	241
Sum	241

Carbon dioxide

Greenhouse Gas, climate changes

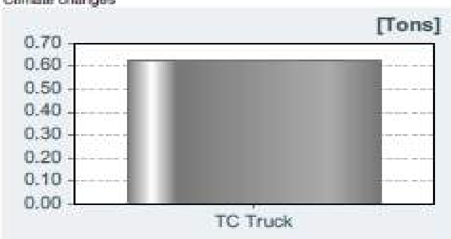


[Tons]

	TC Truck
Truck	0,6
Sum	0,6

CO2-Equivalents

Climate changes

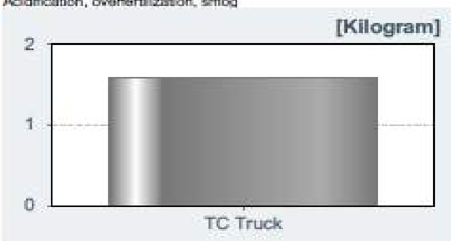


[Tons]

	TC Truck
Truck	0,6
Sum	0,6

Nitrogen oxides

Acidification, overfertilization, smog



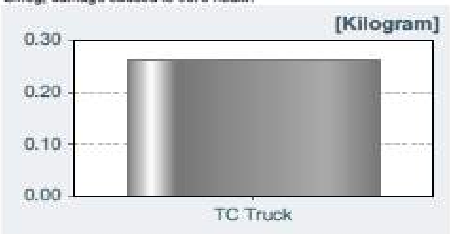
[Kilogram]

	TC Truck
Truck	2
Sum	2

Result of carbon emission of conical can scenario (3)

Nonmethane hydrocarbon

Smog, damage caused to so.'s health



[Kilogram]

	TC Truck
Truck	0,3
Sum	0,3

Sulfur dioxide

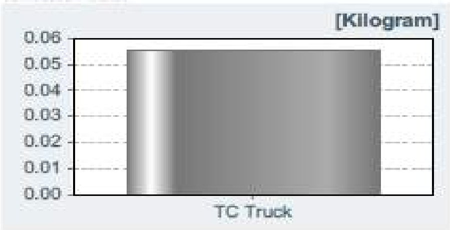
Acidification, damage caused to so.'s health

[Kilogram]

	TC Truck
Truck	0,7
Sum	0,7

Particulate matter

combustion related

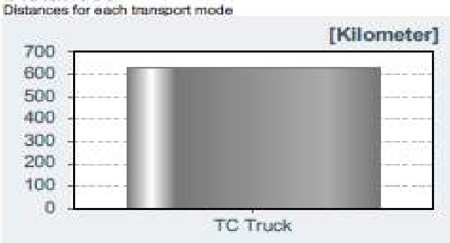


[Kilogram]

	TC Truck
Truck	0,06
Sum	0,06

Distances

Distances for each transport mode



[Kilometer]

	TC Truck
Truck	633
Sum	633

Result of amount of cylindrical can for a single journey of conical can emission (1)

EcoTransIT - Ecological Transport Information Tool

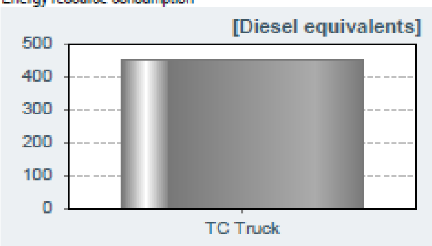
The Ecological Transport Information Tool (EcoTransIT) calculates and compares the environmental impacts of goods transported by different modes. EcoTransIT compares the energy consumption, greenhouse gas and exhaust emissions of freight transported by rail, road, ship and aircraft.

Calculation parameter	
Creation Date:	11.11.2014
Origin:	55.5518549 / 13.046955199999957
Destination:	59.14192119999999 / 18.123756700000058
Cargo weight:	25.2 ton (t/TEU: 10.5)
Input mode:	Standard

Transport Chain Road - 632,59 km	
Origin:	55.5518549 / 13.046955199999957
	Road (26-40 t, EURO-V, Load factor:60.0%, ETF:20%, Ferry routing normal)
Destination:	59.14192119999999 / 18.123756700000058

Amount of cylindrical can for a single journey of conical can emission (2).

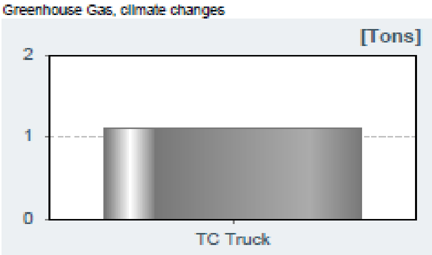
Primary energy consumption
Energy resource consumption



[Diesel equivalents]

	TC Truck
Truck	453
Sum	453

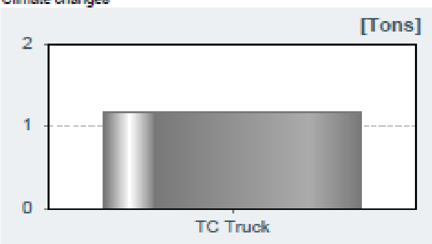
Carbon dioxide
Greenhouse Gas, climate changes



[Tons]

	TC Truck
Truck	1
Sum	1

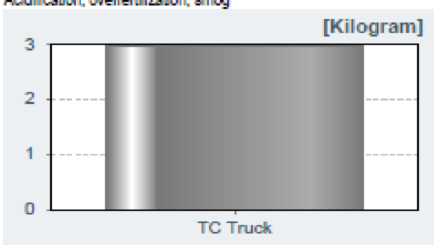
CO2-Equivalents
Climate changes



[Tons]

	TC Truck
Truck	1
Sum	1

Nitrogen oxides
Acidification, overfertilization, smog

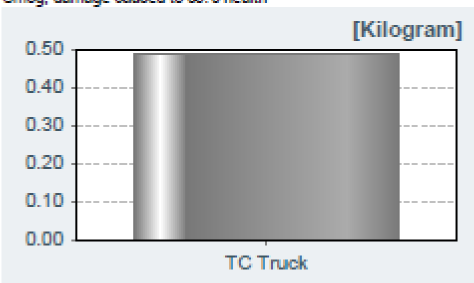


[Kilogram]

	TC Truck
Truck	3
Sum	3

Amount of cylindrical can for a single journey of conical can emission (3).

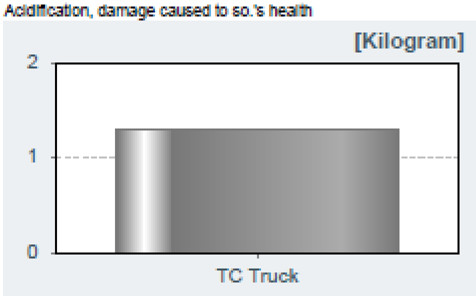
Nonmethane hydrocarbon
Smog, damage caused to so.'s health



[Kilogram]

	TC Truck
Truck	0,5
Sum	0,5

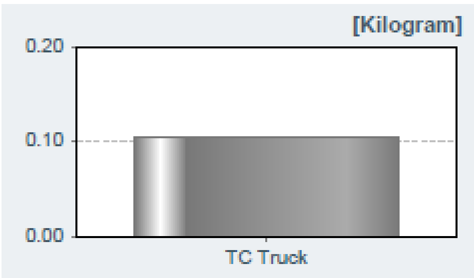
Sulfur dioxide
Acidification, damage caused to so.'s health



[Kilogram]

	TC Truck
Truck	1
Sum	1

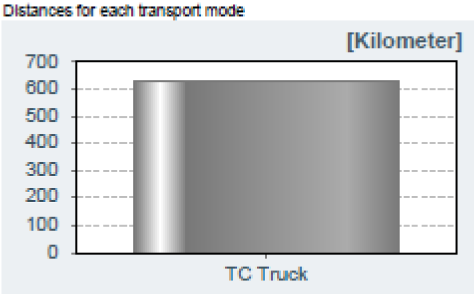
Particulate matter
combustion related



[Kilogram]

	TC Truck
Truck	0,1
Sum	0,1

Distances
Distances for each transport mode



[Kilometer]

	TC Truck
Truck	633
Sum	633

APPENDIX 14

Example of the conical aluminum can.

Example of the cylindrical aluminum can.