Environmental Impact of Packaging

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Abstract

In recent years, the evolution of the global industry has led to an urgent call to change the economy's paradigm to fight climate change. A shift from the current "take-make-dispose" approach to a circular economy is needed in order to reduce emissions of greenhouse gases.

In this work the focus is on packaging which is one of the several areas that industries have been investigating regarding sustainable development aiming the implementation of the circular economy model. The current situation of packaging used by Corbion has been assessed highlighting emerging trends, main concerns, and requirements across different geographies. The evaluation of the environmental impact of packaging alternatives is made by using a Life Cycle Assessment (LCA) methodology through a cradle-to-grave approach. The results are classified per region and are expressed through a set of impact categories: Global Warming Potential, Nonrenewable Energy Use, Renewable Energy use, Land Use and Water use.

Material production has proven to be the life cycle stage that has the highest impact in the analyzed categories while transport is the stage with smallest contribution. Moreover, several scenarios are analyzed to study the viability of improvements on the impact of packaging. These improvement scenarios include the use of recycled and biobased materials, the reduction of material content or the possibility of reuse and reconditioning of packaging. Results demonstrate the existence of potential for improvement of the environmental performance of packaging.

Keywords: Packaging, Life Cycle Assessment (LCA), Environmental Impact, Cradle-to-grave

1. Introduction

Over the past years, there has been an increasing pressure in the economy caused by population growth and increasing urbanization. The global population is expected to reach 9 billion people in 2050 and 11.2 billion by 2100. [1]

The United Nation estimates that by 2050 68% of the world population will live in urban areas [2]. This level of urbanization combined with the current consumption patterns puts a heavy pressure on the economy that needs to be able to attend to consumer demand and to develop a system of distribution that ensures a fast, safe and effective delivery of goods.

Due to this economic development many industries, packaging included, felt the need of accelerating its growth. This pressure on the industry was inevitably accompanied by several environmental harmful issues such as air, water and soil pollution, acidification of ecosystems and climate change.

In recent years, environmental concerns related to packaging, with great emphasis on plastics, became relevant. Although plastic is not the only material that constitutes packaging, there is no doubt that it is indeed one of the most used.

The huge growth of plastic production and consumption is very worrying as most of it ends up in streams, rivers, and ultimately in oceans. "Only 9% of all plastic has been recycled" and "Only 12% has been incinerated" [3] Rethinking all the plastic packaging production and supply chain is thus mandatory. Besides the plastic waste problem, many other causes are identified as being seriously harmful to the environment and responsible for significant climate changes. Globally speaking, in the origin of these damages inflicted on the environment is the "take-make-dispose" model of consumption which is the basis of the linear economy concept.

According to this model, the standard procedure of the industry is to extract resources from nature and use energy to convert them into certain goods which are then sold to an end consumer. After their usage most of these products are discarded when they no longer satisfy its purpose. To support this procedure 65 billion tonnes of raw material entered the economic system in 2010 and this number will continuously grow reaching 82 billion toned in 2020. [4] Significant material resources are thus being explored at an irresponsible rate creating short-term prosperity.

Continuing to follow this pattern of conducting business would mean that all that raw material would become waste, failing to capture possible value. The recognition that human action greatly influences these changes puts most industries under tight scrutiny pushing them to engage in global solutions aiming carbon neutrality. It is an absolute priority to come up with sustainable alternatives.

While many companies are still seeking to understand the benefits of the transition from linear to circular economy, fortunately, a significant number of other companies are already seriously planning to make the shift. These companies understood the great benefit of keeping products and materials in use longer as this mean less resource extraction, less risk in supply chains and less environmental impact. They recognize the need of a more sustainable business activity and are including sustainability in their actual decision-making strategy.

The transition of linear to circular economy is not simple, however. In a first approach, companies must evaluate and seek for solutions to decrease their dependence on finite natural resources. An important issue is also to evaluate how much waste a company generates throughout the life cycle of their products.

Corbion is the global market leader in lactic acid and its derivatives, and a leading supplier of emulsifiers, functional enzyme blends, minerals, vitamins and algae ingredients. It uses its expertise in fermentation and other processes in order to deliver sustainable solutions in the fields of food production and preservation, health and bioplastics. Corbion is highly committed to contribute to a sustainable environment and it is actively engaged in aligning their goals keeping in mind the Sustainable Development Goals, proposed by the United Nations. It is within this context that this work is included.

2. Methodology

2.1 LCA

The LCA methodology used in this work is performed according to the International Organization of Standardization (ISO) standards. According to these standards an LCA study needs to be carried out in four phases: Goal and scope definition, Life Cycle Inventory Analysis (LCI), Life Cycle Impact Assessment (LCIA) and Interpretation.

3. Goal and Scope

The goal of the study is to assess the situation of different packaging used in Corbion in order to understand what are the requirements and expectations of each region where the company is based. It also focuses in quantifying its environmental impact, through a cradle-to-grave approach to identify the most critical packaging life stages. Through this approach it is possible to identify improvements in order to decrease environmental footprint.

The functional unit of an LCA is a quantified reference unit for all inputs and outputs of the study. Results are given per one piece of packaging.

The geographical scope of this study comprehends the regions where Corbion production facilities are present: Netherlands, Spain, Brazil, USA and Thailand.

The LCA models were created using the SimaPro 9.1.0.8 software developed by PRé Sustainability.

3.1 System Description

This work assesses the life cycle of industrial packaging options that are used by Corbion, from extraction and processing of raw materials to the end-of-life stage. Seven packaging alternatives, of several sizes and materials, were addressed as described in Table 1.

Table 1 *– Summary of packaging alternatives studied in each region*

Country	Type of Packaging
Netherlands	1000 L IBC (Plastic, Steel, Wood pallet); 200 L HDPE Drum;
Spain	1000 L IBC (Plastic, Steel, Wood pallet); 200 L HDPE Drum; 20 L Jerry can
Brazil	1000 L IBC (Wood pallet, Steel pallet) 200, 25 and 50 L HDPE drum
Thailand	1000 L IBC (plastic pallet); 200 L HDPE drum 20 L jerry can
USA	1000 L IBC (Platic, Steel and Wood); 200 L HDPE Drum; 200 L Steel Drum; 1000 kg FIBC; 5, 3.5, 2 Gallon HDPE Pail; 25 kg Carton Box; 25 kg Paper Bag;

It was assumed that packaging weight does not vary between regions.

3.1.2 Boundaries

The system boundaries identify each stage of the life cycle and respective flows that are considered for the results. The entire value chain is covered, as illustrated in *Figure 1* including raw material extraction and processing/production, subsequent packaging manufacturing, as well as, distribution, use stage and finally end-of-life treatment.

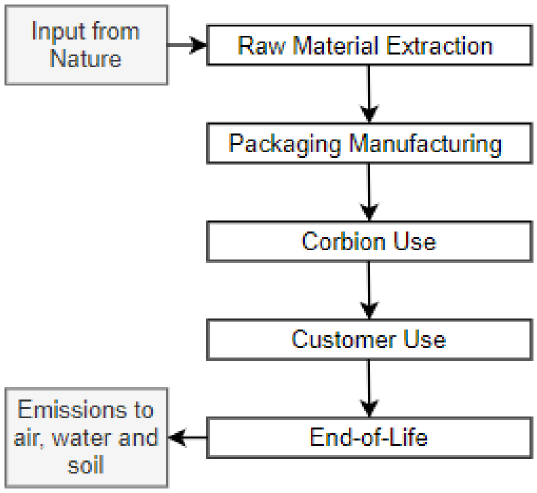

Figure 1 – Simplified Life-Cycle diagram of packaging used by Corbion.

3.2 Life Cycle Inventory (LCI)

Data used to describe each packaging model is based on the Ecoinvent v3.5 database. Specifications of each packaging, such as dimensions, weight, and type of materials were given by suppliers or assumed using literature data.

3.2.2 Manufacturing / Production Stage

The manufacturing stage includes the processing of raw material and its subsequent transformation into packaging.

3.2.3 Use Stage

The use stage of the life cycle is divided in two different sections: Corbion use and Customer use. It describes all the activities conducted by Corbion and by the customer who purchases the product from Corbion. For this work, no impacts associated with the use stage were considered.

3.2.4 Distribution

Distribution is present throughout the whole life cycle as it allows the movement of packaging between each step.

For the cases where transportation was not included in the database, road transportation was considered to be 100 km for each journey.

3.2.5 End-Of-Life

End-of-life refers to disposal for each packaging option and it is the last step of the life cycle. It is determined by material type and region.

The end-of-life accounts for any burdens caused by the waste management including transportation from the consumer to the disposal facility.

Ideally, to get the most realistic scenario, it would be necessary to understand what is the most common disposal of each type of packaging carried out by Corbion's customers. This type of information was not directly available, so disposal was selected by analysing data on average municipal waste disposal or through suggestions from Corbion collaborators working in the specific region. The disposal options considered for each region are presented in *Table 2* – Summary of end-of-life options per region

Table 2 *– Summary of end-of-life options per region*

Country	Disposal
Netherlands	Steel: 100% Recycling Other materials: 80% recycling and 20% Incineration [5]
Spain	IBCs: 80% reconditioned, 20% recycled Plastic (not IBC): 100% recycled Steel: 100% Recycled
Brazil	Steel: 100% Recycled Other materials: 88% unsanitary landfill, 3% open burning, 8% open dump, 1% municipal incineration
Thailand	Steel: 100% Recycled Other materials: 50% Sanitary Landfill and 50% Open dump
USA	Paper: 88% recycled, 12% sanitary landfill [6] Steel: 100% Recycled

3.3 Impact categories

An impact category is an indicator used to quantify different environmental issues. The impact categories identified as being the most relevant to evaluate the environmental performance of the studied packaging options are listed in *Table 3*.

Table 3*- Relevant impact assessment categories*

Impact Category	Unit
Global Warming Potential	kg CO_2 eq
Nonrenewable Energy use	MJ
Renewable Energy Use	MJ
Land Use	m^2a
Water Use	m^3

Global warming potential (GWP) measures the contribution of a certain process to global warming due to emissions of greenhouse gases into the air (most known gases being CO_2, CH_4, N_2O, CFCs, HCFCs and several halogenated hydrocarbons). This impact category is quantified in a time horizon of 100 years.

Renewable and Nonrenewable Energy Use provides the cumulative energy demand (MJ), which measures the total energy use during the life cycle and therefore indicates the impacts of energy consumption.

Land use refers to the impacts caused by occupation, related to a continuous use and managing of land area for human purposes.

Water use measures the volume of water that is required throughout a products life cycle.

4 Sustainable Packaging Market Analysis at Corbion

Evaluation of the current situation in corbion can be accomplished through the understanding of main market trends and concerns from both the company as well as from the customers.

4.1 Netherlands

The Corbion facility in the Netherlands focuses on producing lactic acid derivatives. The types of packaging used must be compatible with these products which are usually liquids.

When looking into packaging, the clients of Corbion in the Netherlands have quality as the first main concern. Nonetheless, it is worth noting that sustainability weights 20% of the decision when choosing packaging. It is not usual for customers to suggest changes in packaging, but they have been expressing concern about the amount sent to disposal, for example.

The Netherlands is one of the five European countries that landfills less than 5% of their municipal waste and is recognized as having the best waste management program in Europe. [7]

4.2 Spain

In Spain, Corbion produces lactic acid derivatives for food and pharma markets. This type of products has implications in packaging due to the extra regulations in place issued by the European commission. The strict rules related to food products will influence packaging, especially when it comes to reuse and using recycled materials. One of the consequences of this is the forbiddance to reuse packaging.

There has been some interest from customers in bio-based plastic, suggesting that sustainability is already a concern. On the other hand, there are still few customers who put sustainability over criteria such as price and quality. The effort of most companies related to sustainability is usually due to regulations.

4.3 Brazil

In Brazil, Corbion has three facilities. One of them produces lactic acid and lactic acid derivatives for food and biochemicals market. The second site focuses on algae ingredients and the third facility produces food ingredients. Due to regulations of food grade packaging, it is not possible to use reconditioned or used packaging.

Sustainability is still not at the core of decision making when it comes to packaging but there is great interest in looking at possibilities and alternatives.

4.4 Thailand

Thailand facility produces lactic acid and lactic acid derivatives for food and biochemicals market. Sustainability is still not a priority within consumers and industry. Packaging quality and price are the main criteria when choosing packaging from suppliers. The number of suppliers in Thailand is scarce and therefore choice is limited.

A high expectation from customers regarding quality exists. However, there is also a reluctancy in alternative packaging such as recycled materials or reconditioning which are seen as affecting quality. In Thailand there has been a contrary shift when choosing packaging. The fact is that there has been interest in using heavier types of packaging specially in IBCs and Drums.

Data regarding Thailand municipal waste disposal policy is limited.

4.5 USA

Corbion facilities in the USA produce lactic acid and lactic acid derivatives for the biochemical and food market as well as emulsifiers (liquids), functional blends (powders) and polymer additives (solid). The different type of products greatly influence the requirements for packaging due to difference in physical properties.

Regarding packaging, the usual requirements from customers are related to safety properties.

Big customers have asked for recyclable packaging, raw material sourcing and biodegradability. They will possibly pay more for a more sustainable alternative.

All packaging must be approved by USA Food and Drug Administration (FDA) which is responsible for public health by ensuring safety.

The Corbion sites in the USA have been making significant efforts in order to improve sustainability performance.

From the collected information, it is possible to draw the immediate conclusion that the situation regarding packaging significantly depends on the country where Corbion facilities are located.

5 Results and Discussion

The role that each impact category plays in the global environmental impact of a given type of packaging is key to understand the contribution of each step of its life cycle and consequently develop targeted action plans. Results are given per region.

The comparison between packaging is made for the same volume and the analysis presented here is done only for GWP impact category. The other impact categories will not be presented.

HDPE, Steel, Wood and Carton parameters, account for the impact of their production considering extraction of the respective raw materials, transportation from the extraction site to the production site as well as the production activity itself. Transportation accounts for the distribution between the manufacture facility to Corbion and Corbion to the customer. Energy is related to the energy used for conversion of the different materials into packaging. And lastly, End-of-life accounts for impacts caused by the waste management activity.

5.1 Global Warming Potential

Netherlands

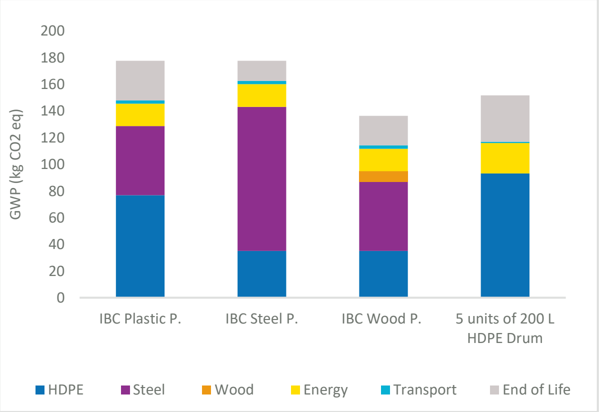

Figure 2*- GWP Assessment of different packaging options in the Netherlands, breakdown by main contributors.*

HDPE and steel production are the main contributors for this impact category as seen in Figure 2. Therefore, the most effective way to have environmental savings in this category would be to approach these two sectors. The production of the materials that constitute the IBC of plastic, steel and wood pallets contribute, respectively, 72%, 81% and 64% for GWP impact. For the five 200 L drums, HDPE production accounts for 61% of the total GWP of this packaging.

Between the three possible IBC's, the option with wood pallet represents a smaller impact. This is caused by the low impact of wood production in GWP compared with steel and HDPE.

The shift from five 200 L PE drums to an IBC with wood pallet allows 10% of savings of the total emitted CO_2.

Transportation is the step that presents the lowest contribution to GWP, therefore possible savings here will not cause significant changes in results. For energy, the contribution varies between 9% of the total impact for the plastic IBC and 15% for the drum.

Spain

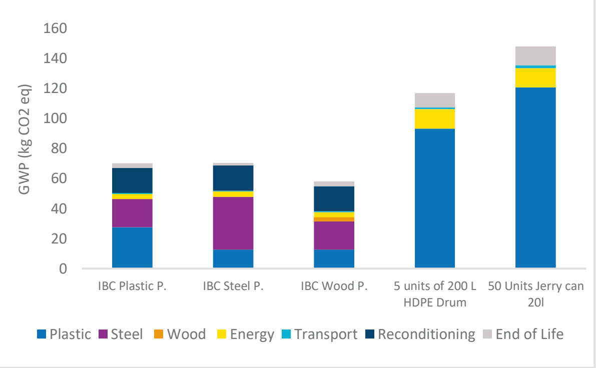

Figure 3 *- GWP Potential Assessment of different packaging options in Spain, breakdown by main contributors*

Due to the presence of Corbion in the food and pharma industry in Spain, only new packaging can be used. In Spain IBC's are sent for reconditioning which means that they will be reused again by other companies.

The "reconditioning" life stage in this model accounts for transportation, for both trips between users and reconditioning facility, solution used to clean the IBC bottle [8] and electricity used in this process [9].

Regarding the IBC's, as seen in Figure 3, IBC with wood pallet is the least impactful of the three possible options.

Using smaller packaging represents higher burdens to the environment. For the same volume of product higher quantities of HDPE need to be produced. Due to its higher plastic content, the end of life of the jerry can is also slightly higher than the typical IBC.

Results show that increasing packaging size such as using drums instead of jerry cans would mean a decrease of 20% in emissions

Thailand

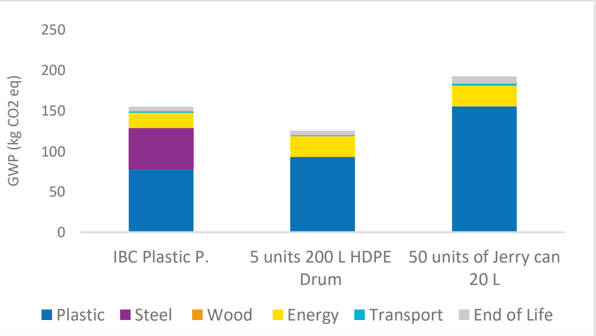

Figure 4 *– GWP Assessment of different packaging options in Thailand, breakdown by main contributors*

From Figure 4 it is possible to conclude that the drum option provides the lowest GWP while the worst contribution comes from the jerry can. This is due to the weight of HDPE production.

Although the IBC with plastic pallet has less amount of plastic it has the additional contribution of the steel cage and therefore the overall impact will be greater than that of the drums.

One possible suggestion for this region could be to convince customers to change from the jerry cans to Drums. With this change it is possible to reduce 35% of the GHG emissions.

Brazil

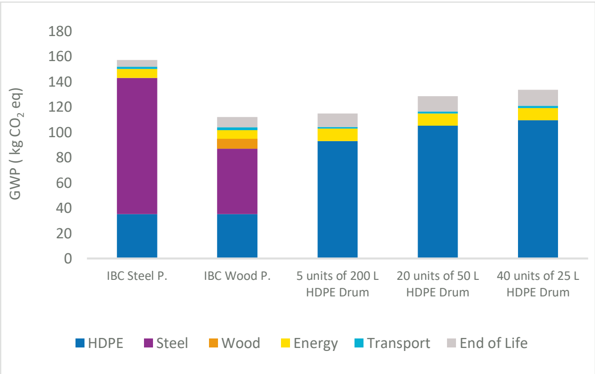

Figure 5 *- GWP Assessment of different packaging options in Brazil, breakdown by main contributors*

Results presented in Figure 5 show that material production is the critical process associated with the environmental impact for GWP. For the smaller drums, 50 L and 25 L, impacts are proportional and therefore for the same volume of product, they are practically the same.

Using the IBC with wood pallet instead of the IBC with steel cage decreases impact on GWP by 29%, equivalent to 45 kg CO2 eq, per each packaging. Also, the shift from the smaller drums to a 200 L drum decreases impact in 14%.

USA

As USA market covers different types of packaging the results are organized according to the nature of packaged products.

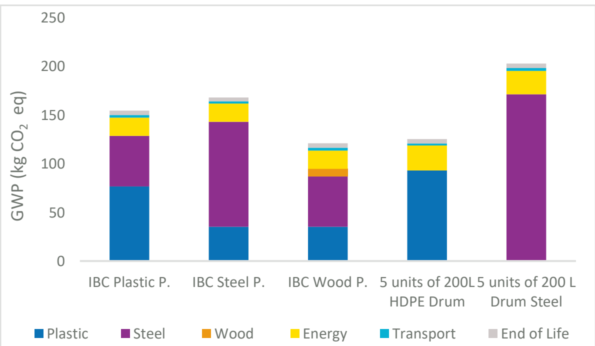

Figure 6 *- GWP Assessment of different packaging options for liquid products in the USA, breakdown by main contributors*

In the USA there are two kinds of drums, steel and HDPE. In Figure 6 steel production has a higher GWP impact than HDPE. For drums with the same size, HDPE production emits 93 kg CO2 eq while steel production emits 171 kg CO2 eq.

A 200 L steel drum corresponds to more 38% in emissions than a plastic drum. Thus, if there are no restrictions, it is environmentally preferable to use plastic drums. Figure 6 shows that the IBC with wood pallet and the 200 L HDPE drum are the most preferable options. Neither end of life nor transportation stage appears as an important contributor.

In the United States Corbion offers a diverse selection of emulsifiers and functional blends. These solid products require different packaging alternatives due to different physical properties Figure 7 the results for packaging of solids.

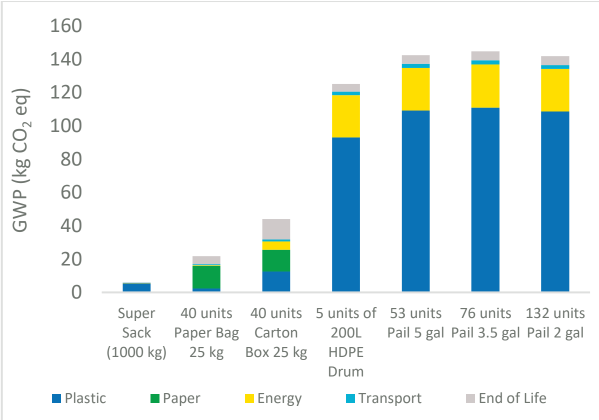

Figure 7 *- GWP Assessment of different packaging options for powder products in the USA, breakdown by main contributors*

The aspect that draws more attention is the significant different results between the several packaging alternatives. Both paper options offer a much lower impact when compared to the HDPE options.

The main contributor for GWP is plastic production due to the use of fossil resources. When replacing plastic for paper, the production stage will contribute significantly less to GWP.

The super sack option displays the lowest impact of all alternatives. This low contribution GWP is due to the low quantity of materials needed to achieve a big volumetric capacity. The content of plastic in the super sack is 17 times less than the HDPE drum and less 20 times than the 5 gallon pail.

As to the three studied pails, impact is the same. This occurs because inputs were directly proportional.

The shift from carton box to super sack saves 90% of emissions for GWP and also provides less landfill volume which has a positive impact both in sustainability as well as in cost.

Switching the carton box for paper bags, as shown in Figure 7 would provide a decrease of 50% of GHG emissions.

6 Improvement Scenarios

The following scenarios present quantification of savings in GWP for several possible improvements.

6.1 Recycled Plastic

Results shown in Figure 8 study the consequences of decreasing the amount of virgin HDPE and substituting it with recycled HDPE. The option of having 50% of a recycled 200 L drum is considered.

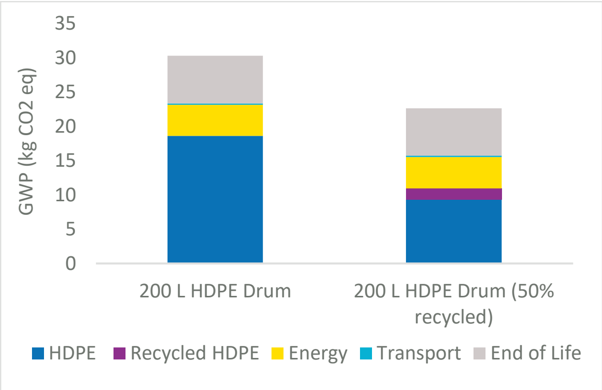

Figure 8 - GWP assessment of HDPE drum considering 50% of recycled content

Results indicate that using 50% recycled material for the drums saved 4.2 kgs of virgin material thus resulting in a reduction of 41% of emissions.

6.2 Steel vs. Recycled Steel

Steel production is one of the largest impactors of GWP in the life cycle of the studied packaging. Thus, it is relevant to examine the effect of using recycled steel and study how recycling might affect its contribution to GHG emissions. The option of having a 100% virgin steel drum was considered for comparison reasons. Thus, extreme scenarios were presented, i.e., the utilization of 100% virgin material in steel production or of 100% recycled steel made from steel scrap.

The model used for steel in Simapro considers an average consumption mix of recycled and virgin steel used in the industry (43% is recycled steel and 57% is primary steel.)

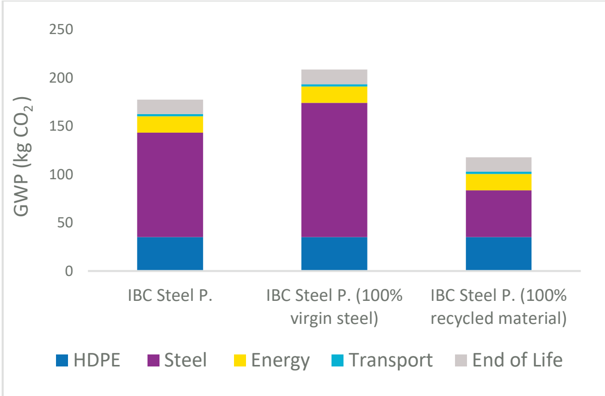

Figure 9 - GWP assessment of IBC with steel pallet considering different amounts of recycled steel content

The way steel is produced will greatly influence results. Considering the average consumption mix instead of 100% virgin steel, as seen in Figure 9, it is possible to decrease emissions by 15%. Ideally, if it was possible to reach the goal of 100% recycled cage and pallet, this decrease would be 44%.

6.3 Bio-based Packaging

Bio-based plastics represent an emerging field. Bio based PE can be obtained from sugar cane, sugar beet and from starch crops *[10]*. In this context, a bio-based HDPE was evaluated as an alternative to HDPE from fossil fuels. This bio-based PE is produced from sugar cane *[11]*, and it is chemically identical to the conventional polymer derived from oil and so it can be used in the same applications.

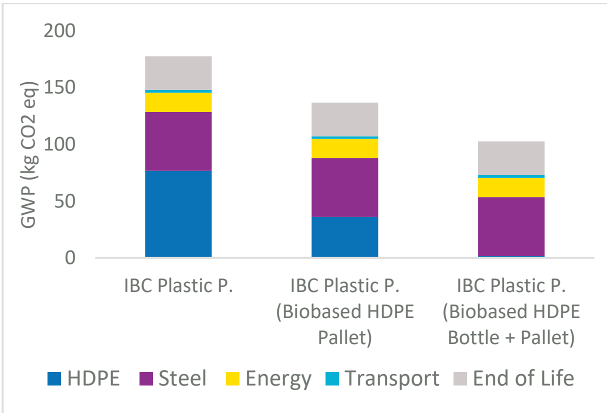

Figure 10 - GWP assessment of IBC with plastic pallet considering the usage of biobased Polyethylene plastic

Figure *10* presents the GWP for 3 packaging options: IBC using both bottle and plastic pallet from fossil based HDPE and two other options, the first concerning a bio-based polyethylene pallet and the last being an option where all plastic used is bio-based PE.

Bio-based plastic has a lower impact than the fossil-based HDPE. The model for bio-based plastics model was based in a study [12] which takes into consideration credits in electricity cogeneration as well as in land use change credits. The accounting of these credits reduce impacts and it is part of the explanation for the significant difference in the results. The HDPE production contribution also decreases massively with the use of biobased PE due to the avoidance of fossil based resourced.

The use of bio-based plastic reduces emissions, allowing 23% of reduction when changing the pallet and reaching 42% when replacing both bottle and pallet for bio-based options. This reinforces the conclusion that the use of bio-based materials reduces greenhouse gases, enabling to shift away from fossil resources.

6.4 Pallet Reuse

This scenario studies the influence of pallet reuse in the GWP impact category.

According to [13], wooden pallets usually can perform between 5 and 30 cycles while plastic pallets have a longer lifetime expectancy, lasting between 20 [14] to 100 cycles. Regarding steel pallets, some reports [14] state that they can be used for 2000 reuses whereas some other [15] states that the maximum is 1000. This scenario was done using the average reuse times of each pallet, 60 cycles for the plastic pallet, 17.5 cycles for wood pallet and 1500 cycles for steel pallet.

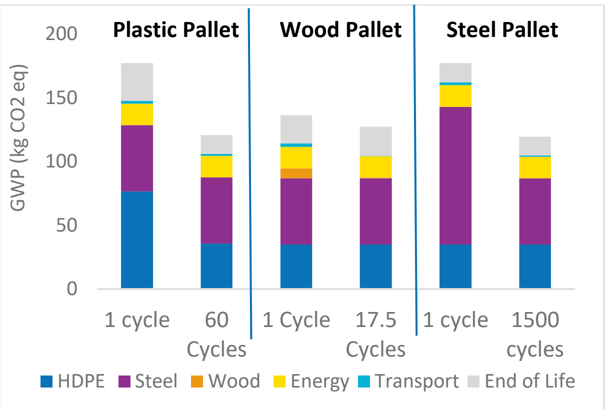

Figure 11 - Comparison of GWP impact assessment of IBC varying the reused times of each pallet

It was assumed that the energy impact is constant and that it is not affected by the reuse of pallets.

Results, shown in Figure 11, indicate that the most affected life steps by reuse are production and transport for the three pallets and additionally end of life for the plastic pallet. If a pallet is being used more than one time, it implies that less material is being used per life cycle which consequently affects the environmental performance. Not only HDPE production decreases but transportation is also less as trips from pallet production to customer have been eliminated.

Reusing pallets considering the average number of reutilization cycles results in a decrease of 53%, 94% and 52% of material production impact for plastic, wood and steel pallets respectively.

The difference of GWP impact for wood pallet between no reuse and reuse was only 6%. For the plastic pallet and steel pallet, the total quantification of savings was 32% and 33%, respectively.

IBC with wood pallet was shown to be the best IBC option in respect to GWP. The of reuse plastic or steel pallets causes GWP impact to be lower than the impact of IBC wood pallet. Therefore, to obtain a more accurate impact of packaging in Corbion it is necessary to investigate how pallets are being handled by customers.

6.5 Reconditioning of IBCs

The aim of this section is to understand the effect of using reconditioned IBC's on GWP impact. IBC with plastic pallet was the chosen IBC to perform this scenario.

For the reconditioning scenario, it is considered that the cage, pallet and bottle are reused 5 times. This means that for 5 reuse cycles, production of bottle, pallet and cage will only happen one time. Contrarily, if there is no reconditioning, materials need to be produced for each use.

The study of the environmental impact presented in Figure 12 is done per use. To model each use in Simapro, the materials necessary for production can be distributed evenly per reuse cycle and so, for each reuse cycle only 1/5 of materials are considered.

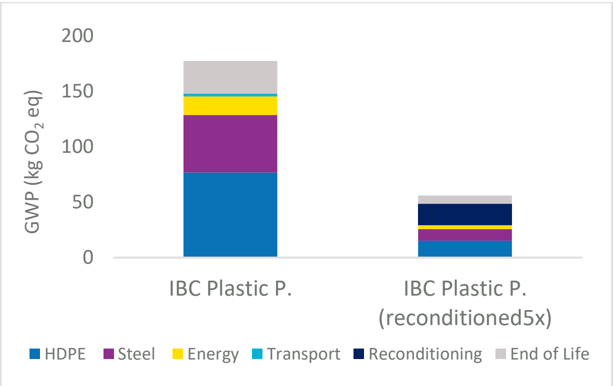

Figure 12 - Comparison of GWP impact assessment of IBC with plastic pallet new and reconditioned

The total impact is considerably lower in the case of the reconditioned IBC. The impact of the production of HDPE and steel, which are the highest contributors for emission, are 1/5 of the value in the case of the reconditioned alternative. However, in the life cycle of the reconditioned IBC, there is an extra contributor which is "Reconditioning". This component includes the 4 batches of cleaning solution, and all the transportation associated to the reuse of pallets. "Reconditioning" accounts for 34% of the total GWP. The global reduction that is possible to attain with this scenario would be 68%.

6.6 Decreasing Plastic Content

This scenario studies the influence on GWP of reducing the amount of plastic used in each packaging. One of the most recent trends within the packaging industry is the elimination of unnecessary materials and the decrease of material usage, especially plastic packaging.

The scenario was modelled decreasing 10, 15 and 20% of plastic weight of 200 L HDPE drums. It was not assumed any change in electricity and therefore its contribution will remain the same for all alternatives.

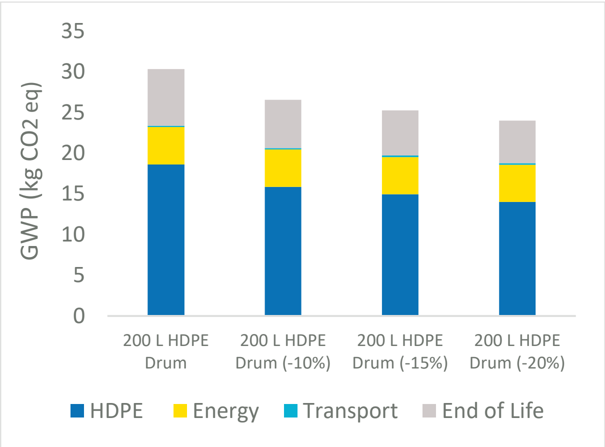

Figure 13 - Comparison of GWP impact assessment of HDPE drums with different plastic content

From *Figure 13*, it is seen that overall GWP contributions decrease with the decrease of plastic content. This reduction occurs in both production and end-of-life parameters. By decreasing plastic, less material will be sent to disposal which will naturally result in a reduction of end of life contribution.

6.7 Carton Box without Lining

Eliminating the lining from the carton box could be an efficient way to decrease plastic usage. Due to the fact that most of these types of products are produced in the USA, this model was developed for this geography.

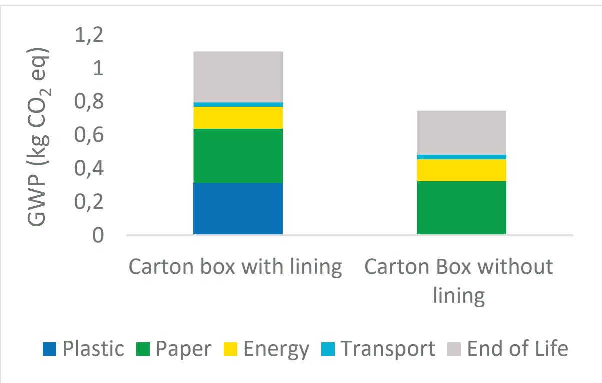

Figure 14 - GWP impact assessment of Carton Box with and without HDPE lining

From the results presented in Figure 14, it is seen that excluding the plastic liner eliminated all plastic production impact. Moreover, the elimination of plastic liner also influenced end of life as the contribution of this stage decrease 14%. The removal of the plastic lining represents a 32% reduction in the global warming potential category.

7 Conclusions

The purpose of this dissertation was to improve understanding of the current packaging situation, highlighting concerns and requirements of each region where Corbion facilities are located, namely the Netherlands, Spain, Brazil, Thailand and the USA, as well as providing a detailed cradle-to-grave description of the different packaging alternatives and associated environmental impacts.

The assessment of the current situation, carried out by gathering and processing information obtained from several departments across all regions, evidence that sustainability is seen as a key factor for development, but also that its degree of importance varies between country. This variation is mainly due to cultural values, environmental awareness and to local government regulations. The main priority of customers is still quality and price but there has been some concern regarding more sustainable packaging alternatives. In the Netherlands, sustainability weights around 20% of the decision when choosing packaging from suppliers. Customers, in Spain and in the USA, have shown interest in biobased and recycled options. Although in Brazil sustainability is not at the core of decision, Procurement has demonstrated interest in studying different packaging alternatives. Thailand, on the other hand, is the region that takes less notice to the environmental performance of its packaging and discussions with packaging suppliers focus mainly on quality and price.

Taking the whole life cycle of each packaging into account, results demonstrate that, for all five regions, the main contributor for environmental impact is the material production stage This indicates that recommendations for reducing environmental performances of packaging should be mainly focused on this life stage. The transportation stage is the stage that shows less contribution for impact.

The packaging options that were studied vary with region given the fact that different geographies have distinct products and requirements. For the USA, paper options were considered, contrarily to other regions. Due to the low impact of the production of paper, results evidence that all paper options perform better than the other possible choices. The shift between smaller packaging into larger options should be carried out whenever possible as it often contributes to the decrease of GHG emissions.

The study of different scenarios demonstrated that there is significant potential for reduction of environmental impact. Following one of the major trends of packaging industry in material reduction, results show that decreasing plastic content, either by decreasing wall thickness of drums or by removing plastic lining of corrugated boxes, translates into savings. Additionally, replacing virgin material for recycled material exhibits improvements on its environmental performance. Using 50% of recycled HDPE in the 200 L Drum and in the IBC with plastic pallet show a reduction of 41% and 18% in GWP, respectively. On the other hand, the usage of 100% recycled steel in the IBC with steel pallet translates to 44% of savings in GHG emissions. Furthermore, the usage of bio-based plastic enables the shift away from fossil resources and consequently decreases GWP impact. These are some examples of possible changes that could be introduced in order to improve the environmental performance of the packaging used by Corbion.

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