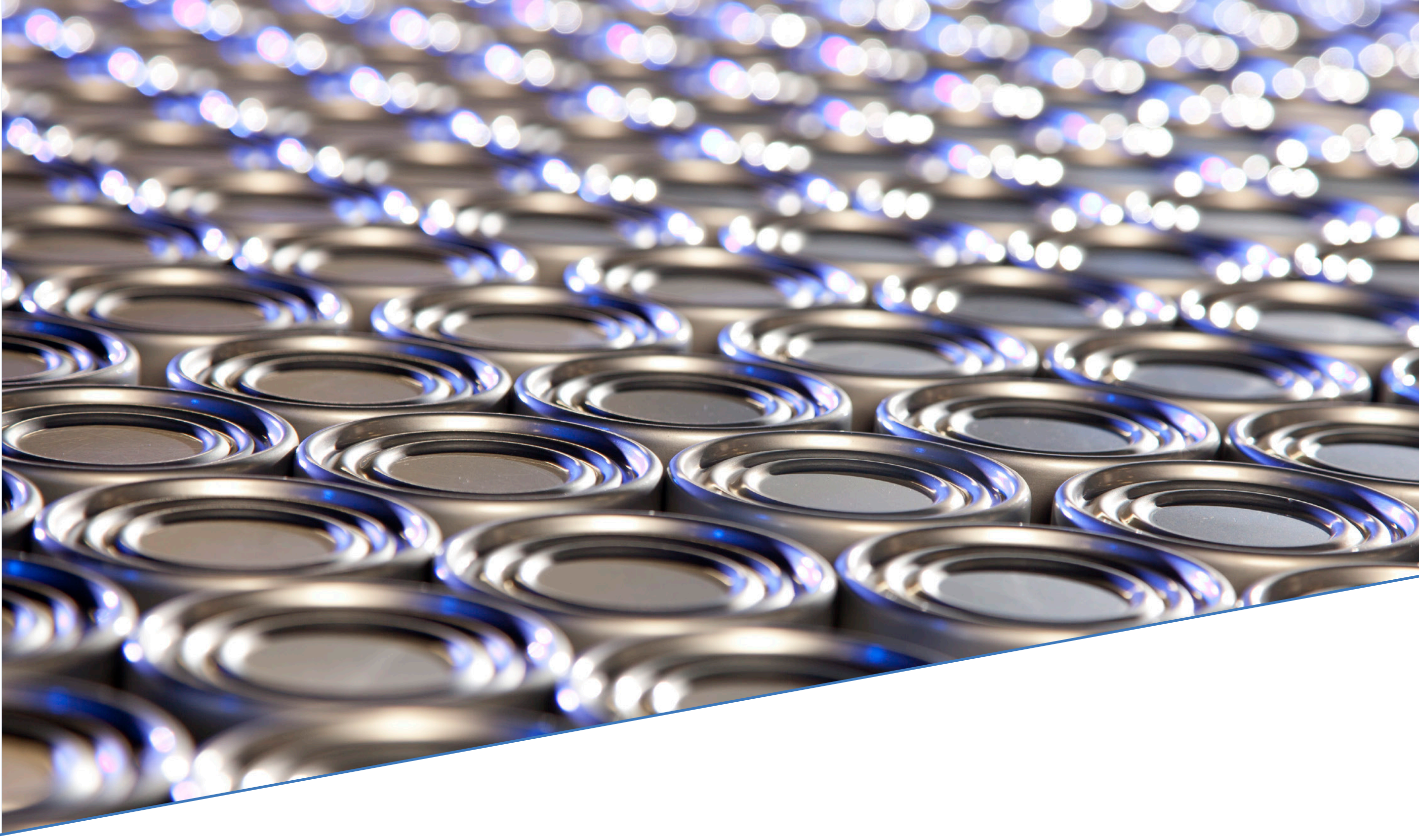

The Future of Packaging: Evaluating Protact® for Reusable Packaging

This thesis report presents a comprehensive material analysis and reusability assessment of Protact®, evaluating the feasibility of Protact® in achieving reusable packaging. Including a reusable packaging design and guidelines for implementation.

Master thesis - DPM 2019

Industrial Design Engineering

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UNIVERSITY OF TWENTE.

TATA STEEL

Master thesis
DPM 2019
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Pages
Report: 1-88
Appendix: 1-162

Foreword

My name is Seline Flietstra, and I wrote this thesis report titled " The Future of Packaging: Evaluating Protact for Sustainable and Reusable Packaging" for my master thesis Assignment in Industrial Design Engineering. With a particular emphasis on the master's track Management of Product Development.

Tata Steel Netherlands assigned me the project, which I worked on for 9 months, from September 1, 2022 to July 1, 2023.

Throughout the project, I was given the opportunity to complete the product development cycle from research to detailing phase. As a result, 3D printed models and advice on how to implement the reuse system that is combined with the designed model have been produced.

This project would not have been possible without the assistance of Tata Steel colleagues, and I would like to thank everyone who assisted me throughout the project. I'd like to thank Deborah Ganzinga and Menno de Bruine in particular for their assistance and feedback on my project during the research phase.

This project would not have been possible without the assistance of my UT supervisor, prof.dr.ir. Roland Ten Klooster. Which I'd like to thank for his time and assistance with the project.

I'd also like to thank my Tata Steel project supervisors, Yoyo Chan (former supervisor), Henri Kwakkel, and Marnix Boggeman. Who have always been there for me when I had questions or needed assistance.

Finally, I'd like to thank my friends and family for always lending an ear and providing inspiration when it was needed. I'd like to thank my boyfriend Tom Tiggeloven in particular for always being there for me during the project.

Summary

Plastic waste is a major environmental issue, it has caused disease, drought and air pollution. Plastic waste has only increased the last couple of years. As consumers are used to buying food and throwing the packaging away without thinking about the consequences, this type of packaging is called single-use packaging.

The packaging that is centralised in this thesis report is a reusable packaging. Unlike the single-use packaging this packaging will be able to be reused several times. By doing this the amount of waste generated each year would decline. Once it is implemented and accepted by the consumers.

This project has been carried out on behalf of Tata Steel Europe. The main goals of this project is to determine whether Protact® would be suitable material for reuse, and what a reusable packaging made from Protact® would look like. The packaging designed can be used as inspiration for their customers. This can eventually help them with more sustainable choices.

The project was started by performing research. The research was split into three sections. The first section was market research. This has shown that there are a couple of reuse models that could be chosen. For the consumers the return from home would be the most beneficial, as this require little to no change from them. For the ecosystem it would be better to implement return on the go. This ensures that they would not have to facilitate the transportation to the homes of the consumers. The chosen model is a combination between the both of them. Implementing the reusable packaging in a supermarket that also has a web shop. This allows the consumers to buy the reusable packaging as they would otherwise buy the single-use packaging.

The second section is use and user research. This research has been divided into two parts, one for the consumer and one for the ecosystem. As the benefits and barriers would differ from each other. The research conducted for the consumers show that their barriers to using reusable packaging are the price, the quality of the product, inconvenience of the system, hygienic issues, ineffective communication, risk of unavailability of refills and the perception to reuse. Apart from this there are also several benefits for consumers these are decreased environmental pollution, reduced costs, price incentives, increased customization and convenience. For the ecosystem the barriers are hygienic/food safety, changes required in business model, brand image, traceability issues and the need to collaborate. The benefits for the ecosystem are increased brand loyalty, modern technology, consumer perception of the brand and decreased amount of packaging waste.

The interviews conducted with brand owners and can manufacturers have shown that the acceptability of dents and scratches is very low at this moment.

The last section of the research phase is technology research. This has shown that legislation needs to be considered. At this moment there are only a couple of legislation that are valid for reusable packaging. In the future it is expected for this to become more prominent. Next to this production techniques have been evaluated. The production technique chosen for the reusable packaging is a draw redraw (DRD) for a two-piece can. As this technique has the least amount of weak points.

Another important aspect that has been researched is material research. This was performed in order to determine whether Protact® would be suitable for reuse. During the test two versions of Protact were compared, Protact® PET and Protact® PP. The results from the material research have shown that the choice between either of them has gone to Protact® PP. This is due to its excellence resistance to water. This has been the most important aspect when deciding which coating type to choose. It would be preferred to use a thicker substrate over a thinner substrate as the differences in dents have been shown for it to be significant.

The next step during this project is the design phase. During this phase several ideation techniques were used. Such as brainstorming and mind mapping. This has led to four main concepts. Which elaborate on the idea of increasing the convenience for consumers using the reusable packaging. In order to improve the chance of consumers using the packaging.

The chosen concept utilised several aspect in order to increase the convenience and chance of reuse. In order to increase the convenience the concept uses a transparent cap and an easy pour. The transparent cap allows consumers to look inside the packaging without opening it. The easy pour will provide the consumer with a pouring aid. In order to increase the chance of the packaging being reused the packaging uses a sleeve. This sleeve has multiple purposes. Since it would be best for the environment to reuse one packaging for multiple brand the sleeve will be use to distinguish between different brands. The brand can customize the branding on the sleeve to fit their brand. Apart from this the sleeve also serves as protection for the main can, this will prevent and hide scratches and dents. In order to ensure it is known how often a packaging is actually reused a QR code is placed on the packaging (which will be reused).

In the next phase the chosen concept has been adjusted on some points in order to be able to produce it. Adjustments made include adding embossing on the side of the packaging in order to remove the need for glue directly onto the main can and to help with nesting of the packaging. The size has also been adjusted in order to fit as much food as possible.

The validation of the concept has shown that the easy pour in fact helps the pouring of the food contents. There was no spillage present when pouring with the easy pour, oppose to using no easy pour in which every time some food was spilled. During the validation it was also crucial to determine whether implementing a reusable packaging would indeed be better for the environment. For this a life cycle analysis (LCA) was performed. In this LCA a single-use packaging was compared with the reusable packaging, the product compared has been Quaker Cruesli Luchtig. The LCA has shown that the reusable packaging would be favourable after seven reuse cycles. Using a plastic cap compared to a Protact cap is also favourable.

In order to show what the packaging would look like with different branding several options have been worked out. This shows that changing the branding on the sleeve still helps with distinguishing between brand and ensure the product is recognisable. Lastly, the product has also been placed in its intended environment to show what this would look like.

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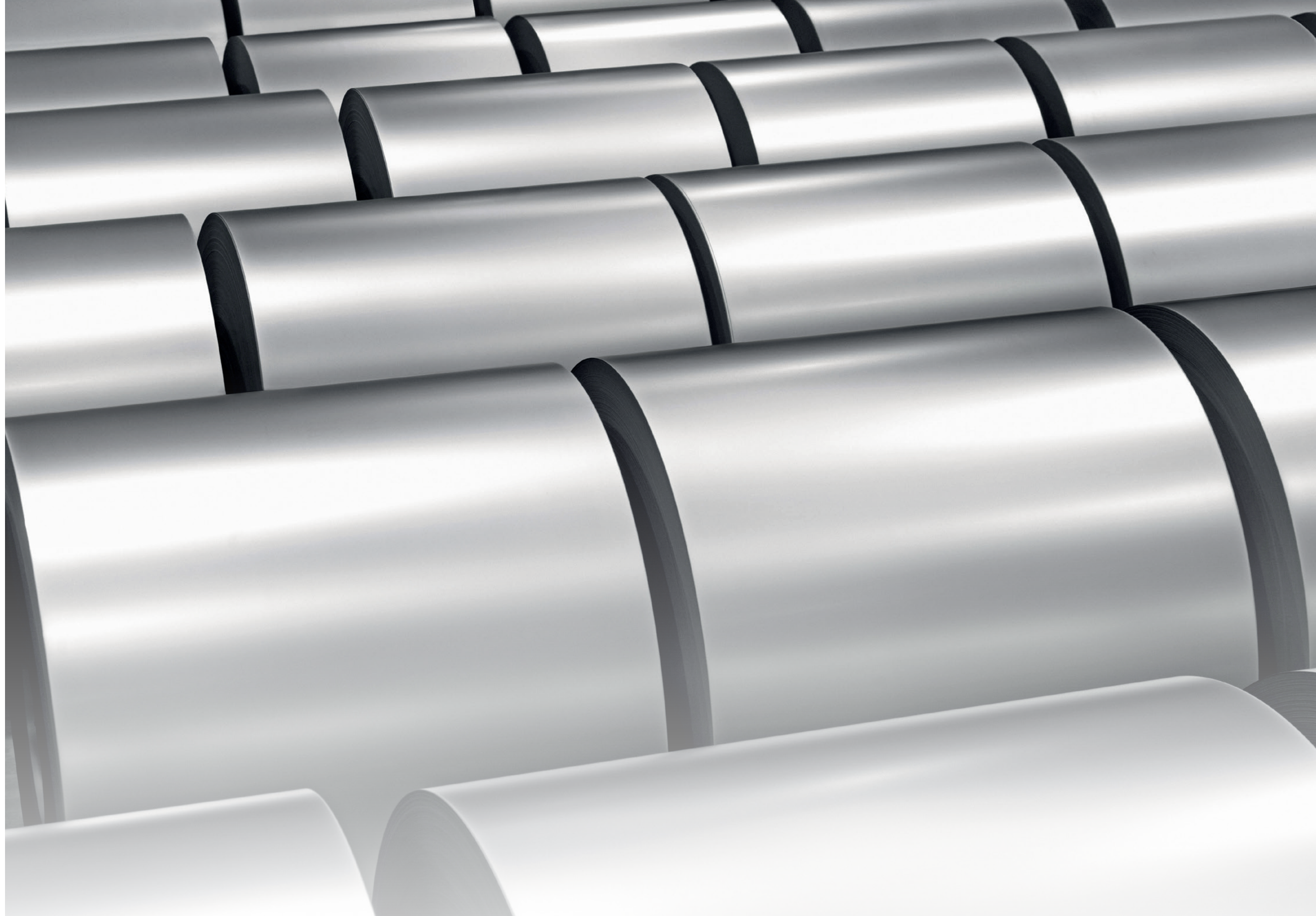
Abbreviations

TSN – Tata Steel Netherlands
TSE - Tata Steel Europe
KIDV – Kennis Instituut Duurzaam Verpakken
SWOT – Strengths, weaknesses, opportunities and threads
2P – Two piece
3P – Three piece
DRD – Draw redraw
DWI – Drawn and wall-ironed
PP – Polypropylene
PET – Polyethylene terephthalate
FT-IR – Fourier-transform infrared
DSC – Differential scanning calorimetry
EDX – Energy-dispersive X-ray
LOM – Light optical microscope
EIS – Electronical impedance spectroscopy
FBB – Folding box board
LCA – Life Cycle Assessment
LC – Life Cycle
ADP – Abiotic depletion elements



Chapter 1: Introduction

The introduction contains information regarding the assignment the company, the material, methods used during the project and lastly the outline of the thesis.

1.1 Assignment

In this report a reusable packaging made from Protact® will be researched and designed. Protact® is currently used for food packaging and is safe to be used for food consumption; however, it has yet to be determined whether this is still true after multiple uses. This is the question posed by Loop (explained in section 1.3) to Tata Steel. Which is also the primary objective of this assignment along with the necessary recommendations for Protact® to be used for reusable packaging. The primary question of this assignment is therefore, "*Is it possible to design a reusable packaging using Protact®, preferably for the food industry and the European market?*" In addition to the primary question, a number of secondary and tertiary questions have been created. They are listed below:

1. Is Protact® suitable for packaging that will be reused?
2. How should Protact® packaging that is reusable be introduced to the market?
3. Is Protact® packaging that can be reused more environmentally friendly than single-use packaging?
4. How would you recommend designing a reusable packaging made from Protact?

The packaging must withstand multiple reuse cycles. From packing the product to returning it to the store. During this cycle, the product will be heavily utilised, washed, and transported. The washing procedure will be carried out in conjunction with Loop. Therefore, the packaging must be able to withstand at least ten washing cycles provided by Loop (see 1.3) or another alternative must be suggested. The packaging must also be technically feasible, producible, and reusable. Additionally, it is essential to evaluate the sustainability of the packaging, as it must be determined whether reusable packaging is more sustainable than single-use packaging and from how many cycles this is the case. Finally, a business model will be created to demonstrate the optimal method for introducing the newly designed reusable packaging to the market.

1.2 Tata Steel

Koninklijke Nederlandse Hoogovens was established in The Hague in 1918 [1]. In result, Dutch households became less reliant on metal imports. The company was established in Ijmuiden due to the region's convenient access to the sea for shipping and the export of manufactured goods and iron [1]. Throughout the years, they acquired multiple businesses, including a rolling mill company. British Steel and the Koninklijke Nederlandse Hoogovens merged in 1999 to form Corus. Tata Steel acquired Corus shortly thereafter, in 2007.

Tata Steel was founded in India in 1907 [2]. In 1910, the first coal mine was acquired, and the following year, the first blast furnace was constructed. Tata Steel employs 75,000 people, has production facilities in twenty-six countries on five continents, and can produce 33 million tonnes of steel annually [3]. They produce metal for the engineering, packaging, construction, and automotive industries. In terms of sales volume, manufactured goods and automotive represent the largest share [3].

Tata Steel Packaging has three divisions [3]. These are in the cities of Duffel in Belgium, Ijmuiden in the Netherlands, and Trostre in the United Kingdom. The Netherlands is home to the company's largest manufacturing facility. During this project, the packaging division of Tata Steel Europe will be emphasised. This segment includes food packaging, aerosol packaging, general packaging, and beverage packaging. The focus will be placed on food packaging, as this is the preferred area to concentrate on when designing the packaging.

Vision
The vision of Tata Steel is "We aspire to be the global steel industry benchmark for value creation and corporate citizenship" [4]. Their innovative approach, people, products, conduct, and policies set them apart.

Mission
Tata Steel's mission is to expand India's industrial base by utilising its workforce and resources effectively. To achieve consistency and high output. They strive to establish a fear-free environment.

Values
Tata Steel upholds five guiding principles [4]. Integrity is the primary value; they seek moral and honest behaviour. They are committed to maintaining high standards of quality, which is the second core value. The third value is unity, which they inspire in their employees and partners. The fourth value is responsibility; they believe that what people put into the world will eventually return to them. They desire to be courageous and adaptable, which is the fifth value. Overcoming obstacles and coming up with innovative solutions.

1.3 Loop

Loop is an organisation that was founded in 2019. Starting the company was motivated by a desire to rid the world of waste, which started with recycling materials that could not be recycled at that time. This included restaurant waste and diapers, since less than 10% of single-use packaging is currently recycled [5]. Loop has initiated a circular system using reusable packaging to combat this issue. For maximum convenience, customers can order multiple reusable packaging and have it delivered to their homes. After using the packaging, they can return it to Loop. In turn, Loop washes the packaging and returns it to the brand owner.

The customer will be required to pay a deposit for the packaging, but will receive it back after returning it to the store.

Loop is always seeking innovative ways to reduce waste. Which also initiated the assignment performed in this paper. As the use of a novel material such as steel may result in more durable reusable packaging. Before Loop can include them in the process, however, the packaging must be able to withstand at least ten reuse cycles and the material must be recyclable. Loop's specifications must also be considered when carrying out the assignment.

1.4 Protact ®

The material referred to as Protact® will be discussed and investigated in this report. Tata Steel produces Protact® in a larger quantity since 2016, Protact® is also produced in England and Belgium. This material consists of a steel layer (substrate) that is surrounded on both sides by a three-layer polymer coating system. Which has been optimised to eliminate the need for costly processes associated with lacquer use [6]. The material has received full approval and is a regulated food-safe product. In figure 1, the layers are visible. When reusing the packaging is no longer possible, the material will be recycled. The plastic will be burned and converted into energy, while the steel can be reused multiple times.

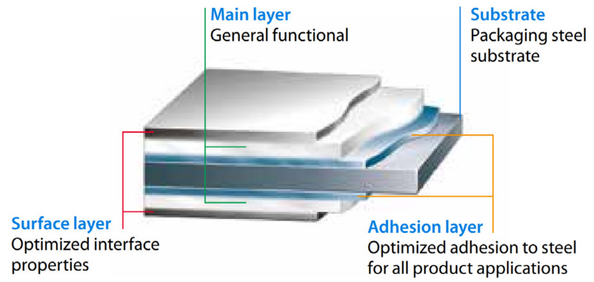


Figure 1: Layers of Protact® [1]

This section will simplify and explain the Protact® manufacturing process in order to facilitate a better understanding of the product. Protact® is manufactured in two stages: film production and lamination. The metal is delivered in the proper dimensions and thickness. The film production line begins with granulates that can be tailored to the customer's specifications. These granulates are stored outside the factory, making it easy to resupply them with outside trucks. The granulates are then dried; before use, certain types of plastic granulate require drying. The granules are then placed inside of the dosing unit. These dosing units (three units, one per layer) are composed of four hoppers, allowing for the combination of four distinct plastic types per layer. The hoppers will deliver the correct amount of material for each layer to the extruders. This will extrude the plastic film when heated.

The casting roll is the subsequent step. This is a roll for cooling plastic film so that it can be stretched. After stretching, the thickness of each section of film is measured; if defects are detected, this machine sends a signal to the extruder to extrude slightly more or less per section. The material is then wound onto a roll and divided in half.

During the lamination step, two three-layer films are adhered to a metal. In the Protact® bonding section, two types of films are inserted based on the customer's preference. In order to properly adhere the plastic to the metal, both the metal sheet and the film must be heated. Following the bonding process, Protact® is dipped in water to cool before being rolled into a final coil.

1.5 Methods used

This thesis addresses its research questions with a variety of methodologies. Along with interviews and a literature review, material research was conducted. Literature reviews were used for background research, consumer research, ecosystem research, the existing reuse system, and the urge to reuse. The literature review is based on scientific papers, journals, and websites. The purpose of the literature review is to provide a deeper understanding of the difficulties and benefits for both the consumer and the ecosystem. Examining current reuse systems reveals the options that are currently available.

The interviews conducted for this research are qualitative. Several can manufacturers and brand owners have been interviewed. This data has been compared to the literature review to determine which areas are identical and whether additional information can be obtained from the interviews.

The material research relies on a variety of tests. Some of which did not exist prior to the project. Included in these tests are those for dent resistance, cleaning, vibration, and various closure testing. The outcome of the test will indicate whether or not the material is suitable for reuse and its durability.

Calculations were then performed to determine the cost price and business plan. An LCA analysis was also conducted to determine whether the reusable packaging is in fact more sustainable.

1.6 Outline thesis

This thesis is divided into nine chapters. The first chapter is the introduction. This chapter will cover general project details, including a description of the assignment and information about Tata Steel Europe.

Chapter two addresses the research phase. In this chapter, there are three sections. The first is market research. This chapter provides information regarding competitors, reuse systems, the ecosystem, and background research. Use and user research covers the second section. Here, interviews and a literature review have been conducted. Technology research is discussed in the final section. This section contains information on production methods, regulations, patents, washing systems, and material research.

The list of requirements is presented in the third chapter. This was created based on the findings of the previous chapter, but it was also revised as the project progressed. This document is updated whenever new information becomes available, as it is a living document.

The design phase is discussed in chapter four. This chapter describes the steps that lead to the final design. This chapter also includes an outline, a morphological overview, and sketches.

The fifth chapter focuses on the detailing phase. During this phase, the design will be analysed and adjusted based on its technical feasibility, details will be presented, the chosen production techniques will be explained, and simulations will be displayed. In this phase, the calculation for sustainability can also be found.

The materialisation phase is discussed in Chapter 6. This phase will consist of a description of the business plan and validation of the selected concept. This phase also includes the business plan with the long- and short-term strategies for both Tata Steel Europe and other interested parties.

The detailing phase is discussed in chapter seven. During this phase, the final design will be displayed in the intended environment. Additionally, similar designs for various brands will be displayed.

In chapter eight, the conclusion of the research is presented. After which the discussion and recommendations are given. Lastly, the evaluation and reflection are described in the final chapter.

Chapter 2: Research phase

This phase contains the results of all research conducted during the project. There are three categories used to organise the numerous studies conducted. These three categories are market research, use and user research, and technical research. To gain a deeper understanding of the market, market research has been conducted. The use and user research phase was performed to gain a deeper understanding of the customer's reasoning. In order to learn more about the technical aspects of this project, such as the material research, technology research was performed.

2.1 Market research

Market research is the first research category that will be discussed in detail. This research was conducted to gain a deeper understanding of the packaging industry. This section contains information on packaging types, waste management strategies, reuse systems, the ecosystem, stakeholder analysis, and competition analysis.

2.1.1 Background research

Packaging

Packaging dates back to the earliest civilizations, when newly captured food was wrapped in leaves [1]. Over the succeeding centuries, an increasing number of packaging materials were developed, facilitating the packaging, storage, and transportation of food. These include glass bottles, paper bags, metal, and later plastic packaging. As civilizations began to gather and settle in a single location, the need for better food preservation and packaging increased. Consumers regarded the packaging as valuable and reused it multiple times [1]. Until the production of plastic packaging became simple and inexpensive. Because it was much more convenient for them, the consumer no longer felt compelled to return the packaging. Currently, the majority of packaging has been replaced by single-use packaging, resulting in a linear economy as opposed to a circular one. However, as time passed, the environment began to change, with sea levels rising and visible garbage accumulations in the oceans. Single-use plastic has a negative impact on our planet [3]. As a result, it is time to reintroduce packaging that can be reused, as it has been for many years.

As stated previously, packaging is utilised for transporting, preserving, and storing products [1,6]. In addition to these advantages, packaging serves an important function for retailers today. It can be used to attract clients [4]. The exterior packaging serves as a form of advertising; the more appealing the packaging, the greater the likelihood that a consumer will purchase the product. According to research, 59 percent of all purchases are impulsive [5] and are therefore influenced by the products encountered while shopping. This demonstrates the significance of packaging in establishing the identity of a product [4].

Types of packaging

There are three packaging types. This includes primary, secondary, and tertiary packaging. Each of these will be explained in greater detail in the subsequent section.

Primary packaging
This packaging type comes into direct contact with the product [7,8]. This type of packaging will inform consumers about the product's composition and brand. As stated in the previous section, the primary packaging also serves to protect the product and prolong its shelf life.

The packaging that will be created in this thesis is a primary packaging. However, the other packaging types will also be considered, as this packaging will also be transported and must be able to withstand any forces applied during transport.

Secondary packaging
The secondary packaging is the packaging used to store the primary packaging. Depending on the nature of the packaging, the level of protection provided by secondary packaging varies significantly [8]. Secondary packaging also includes retail-ready packaging (RRP), shelf-ready packaging (SRP), and counter-top display units (CDUs) [7]. With retail-ready packaging, secondary packaging will also be used for branding, resulting in reduced protection; gift packaging is an example. In this instance, the packaging typically contains only a few primary containers. Secondary packaging used solely for transportation purposes have a higher level of protection. These are also not seen by consumers, as the primary packaging is removed from secondary packaging boxes prior to being displayed in the shop.

Tertiary packaging
Tertiary packaging consists of boxes or pallets upon which secondary packaging are stored. Tertiary packaging facilitates transport and handling. Pallets are the standard for tertiary packaging [8]. In addition to the pallet, another product, such as shrink wrap, is used to secure the boxes to the pallets. However, it is more environmentally friendly to reuse reinforcements. Such as the protection offered by pallet wrap [9].

Waste management strategies

The EU Waste Framework Directive (Directive 2008/98/EC) was examined to determine the place of reuse in society relative to other options. In this directive, the waste hierarchy is depicted using an inverted pyramid. The higher up the waste management pyramid you are, the better the waste management method [10]. Figure 2 depicts the pyramid. The framework describes disposal, recovery, recycling, preparation for re-use, and prevention strategies. This is also the recommended sequence.

Figure 2: EU Waste Framework

Disposal is the method least preferred. As it serves no purpose other than to occupy land that could have been used for something else. It could also pollutes the air, water, and soil [11]. The discarded materials do not generate energy and are typically sent to landfills and sewers. In 2019, disposal (landfill) contributed the most to waste management worldwide, at 49% [12].

Recovery is the second-worst waste treatment method available. Unlike disposal, materials in recovery are burned to obtain energy. Materials that are not recyclable are recovered. In 2019, however, only 19% of global waste was recovered (incinerated) [12].

Recycling is positioned in the centre of the waste hierarchy. This step involves recycling the materials for use in other applications. Because the materials' quality degrades, they cannot be used for the same application; therefore, recycled materials are used for products with fewer requirements. However, this is not the case for all materials for example steel remain the same quality even after recycling it several times. In 2019, only 9 percent of waste is recycled globally [12].

Preparing for re-use is the second-best method for waste management. This technique relies on reusing materials for the same purpose. Considering that it has received the proper treatment prior to re-entry, particularly for food-grade products. There are no statistics on product reuse because the product is not yet waste at the time of reuse.

Prevention is the best and final strategy for waste management. The greatest amount of waste can be avoided by simply reducing the number of products manufactured and the amount of materials used. Similar to reuse, this method does not correspond to a specific number. Because it is significantly more difficult to calculate how much material was avoided globally than the amount of waste produced.

In addition to these waste management techniques, there is a substantial amount of waste that is never collected. These contribute to improper waste management. In 2019, 22 percent of global waste was not collected or was improperly managed [12]. This item will never reach the top of the waste management pyramid. Mismanagement of waste and improper disposal have the greatest impact on the environment.

R-ladder

The KIDV (kennis instituut duurzaam verpakkingen) has developed an R-ladder [13]. Other waste management strategies than recycling and reuse are discussed in this section. Repurpose, remanufacture, refurbishment, and repair have been added to the list of methods. The first (recycle) and last two (reuse and reduce) strategies on the ladder are identical to those found in the EU Waste Framework Directive. The r-ladder is shown in Figure 3.

Re-purpose is defined as utilising discarded items to create new products with a different function.

Remanufacturing utilises discarded product components to create identically functioning new products.

Refurbishing entails repairing used items so that they can be used again. The objective is to make the product appear brand-new despite the replacement of components.

Repair is the process of restoring a usable item that has not been discarded. This is the last step prior to reuse. Therefore, the best course of action when a reusable item is partially broken is to repair it.

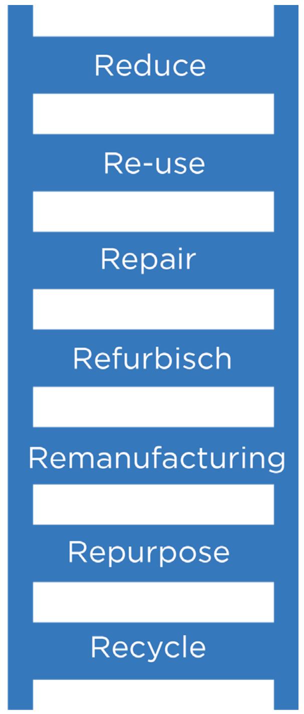


Figure 3: R-Ladder KIDV [2]

2.1.2 Reuse models

The Ellen McArthur Foundation has created the first reuse model that will be discussed [14,15]. This model is comprised of four reuse models. Refill at home, refill on the go, return from home, and return on the go are the four models. Each will be described in greater detail below.

Refill at home
This model works best for online retailers, but it can also be applied to conventional retailers [15]. As the packaging can be refilled at home after the consumer purchases a refill in-store or online. The model is illustrated in figure 4.

Reduced transportation and packaging costs are among the benefits of this model. By offering refill solutions, businesses can increase brand loyalty and allow users to personalise refills, for instance.

Attracting consumers to packaging of a smaller size may prove difficult, as may convincing them that the smaller package contains the same amount of product as the larger one. A further obstacle is ensuring that refill packaging is reusable, recyclable, or compostable.

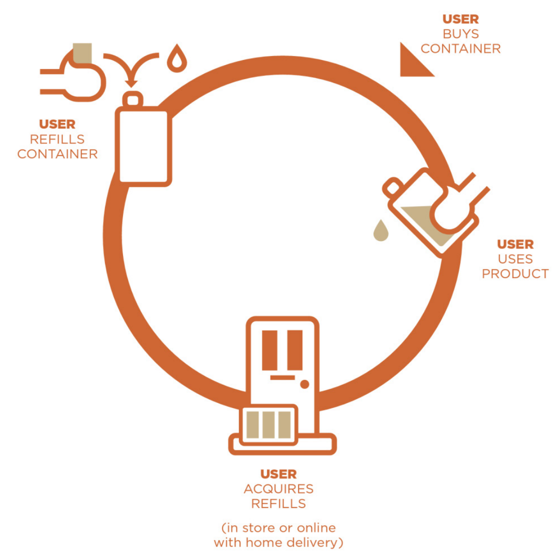


Figure 4: Refill at home [3]

Refill on the go
Refilling the packaging requires a physical location, so this model only applies to conventional stores. In this model, the consumer must return the empty container to the store in order to receive a refill. Model illustrated in figure 5.

This model has the benefit of allowing users to purchase the quantities they need and customise the contents. By mixing water with the product on-site, businesses can collect information about preferred dispensing methods and reduce transportation and packaging costs. Lastly, the consumer can benefit from the enhanced accessibility of the systems, as they may be mobile or in public spaces.

It could be difficult to convince customers to bring their own containers. Safe and hygienic dispensing could also be a concern. An additional concern is ensuring that the product is filled with the correct brand.

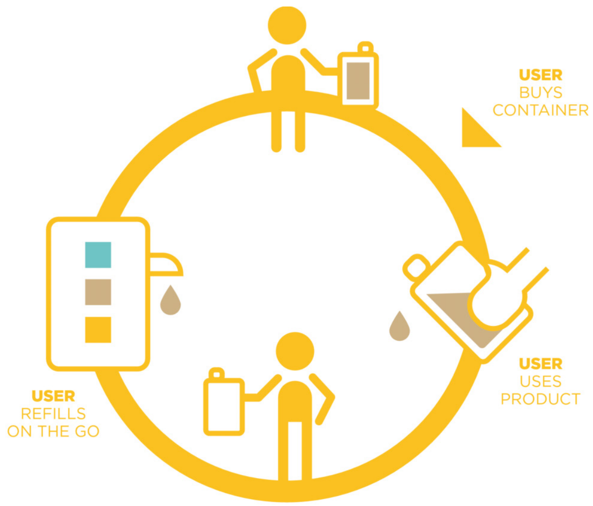


Figure 5: Refill on the go [4]

Return from home
This model is only applicable for e-commerce because they can pick up packages from houses. The product will be delivered to the consumer's home, where they can use it and then return it by pick-up after a period of time. Model illustrated in figure 6.

Consumers are not required to go out of their way to obtain the reusable packaging, which is a benefit. Brands are able to increase brand loyalty. Within a shared system, the return system could be optimised. Customers' preferences can be retrieved by businesses.

Establishing infrastructure for return logistics, cleaning, and restocking can be challenging. Creating the optimal deposit system. The creation of a deposit and pay out system is an additional difficulty. Using this system could also make it difficult to scale quickly.

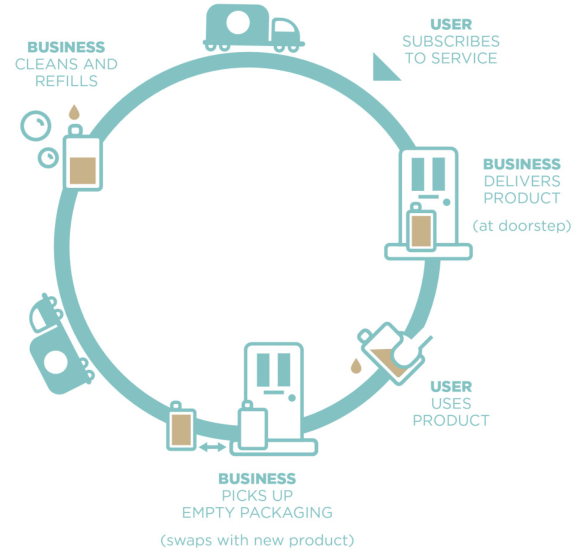


Figure 6: Return from home [5]

Return on the go
This system can be utilised in a variety of settings. As reusable alternatives can be substituted for single-use alternatives. Model is illustrated in figure 7.

This model's advantages include an increase in brand loyalty, the ability to optimise operations through standardisation, and the ability to collect data and determine optimal drop-off locations. In conclusion, aesthetically pleasing packaging can enhance the user experience.

Developing the optimal deposit and reward scheme is problematic. Facilitating consumer returns, establishing a take-back infrastructure, establishing reverse logistics, and developing a system to track deposits and pay outs.

Muranko et al. [16] created the second and last reuse model that will be discussed in this section. This model exists out of five models for reuse. These are exclusively reused products, exclusively reused products with infrastructure that enables reuse, infrastructure that enables reuse for exclusively reused products, sequentially reused products with infrastructure that enables reuse, and sequentially reused products. Each will be described in greater detail below.

Exclusively reused products
In this model, the owner purchases the product once and then reuses it (in this case the consumer). There are no infrastructure offers, as they are unnecessary for the types of products that this model provides. Among these products are reusable water bottles, coffee cups, and single-use alternatives. This model is not included in the model designed by the Ellen McArthur Foundation.

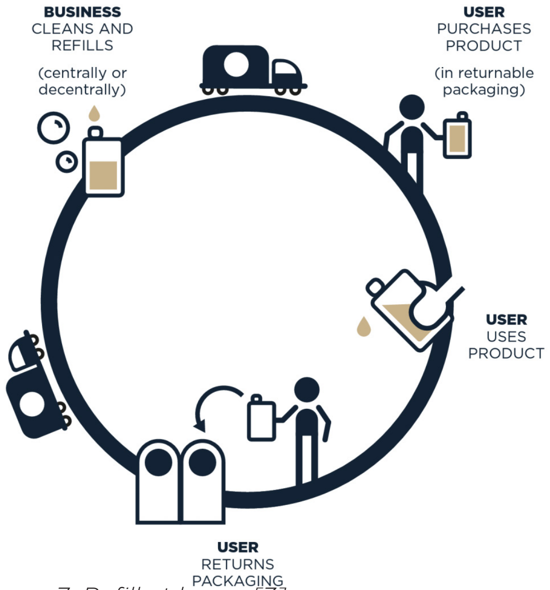


Figure 7: Refill at home [3]

Exclusively reused products with reuse-enabling infrastructure
In this model, the consumer purchases the parent packaging only once and utilises a reuse-enabling infrastructure to reuse the product multiple times. This includes replenishing a product's supply by purchasing refills in stores or online. Sodastream [17] serves as an example of this model. In this model, the parent packaging is owned by the consumer. Similar to the Ellen McArthur Foundation's Refill at Home model, this model is portable.

Reuse-enabling infrastructure for exclusively reused products
This model involves purchasing refills and then filling your empty bottle at home. It provides no packaging; the refill can be placed in any packaging. The consumer is the owner of the packaging in this instance. Refill at Home from the Ellen McArthur Foundation is comparable to this model.

Sequentially reused product with reuse-enabling infrastructure
This model provides the user with a system that allows for packaging refills. The user may utilise either their own packaging or packaging supplied by the manufacturer. Refill on the go from the Ellen McArthur Foundation is comparable to this model. This is illustrated by the already existing reuse system offered by AH in Amsterdam (as stated in the next section).

Sequentially reused products
The producer owns the packaging in this model. Additionally, the manufacturer is responsible for the packaging system and its cleaning. In addition, they ensure that the packaging is safe and reusable. Loop, a participant in this study, is an illustration of this model. This model is comparable to the Ellen McArthur Foundation's return on the go and return from home.

Each of these reuse systems will be considered when selecting the final reuse system for the final packaging design in this project. They will also be used to create customer journeys.

2.1.3 Existing reuse systems

To gather information about the current reuse system, it has been decided to conduct literature research. As this would reveal which systems function well and which do not. This will provide valuable information that will be utilised during the development of the business model.

Currently, the most well-known reuse programme in the Netherlands is for large bottles and beer bottles [18]. This system uses a deposit system that has been quite successful over the past few years, resulting in a 70 to 90 percent reduction in the amount of bottles thrown away [18]. The fact that beer bottles and crates are separated before being returned to the brand owner is interesting about this system. There are currently multiple beer brands that use the same kind of brown bottle. However, brands such as Grolsch and Heineken use their own kind, necessitating that supermarket employees separate them. This should be considered, as too many different types of containers (such as beer bottles or other packaging) would demand manual sorting and additional storage space. Which could be a challenge for supermarkets when implementing these systems for other purposes.

Compared to consumer markets, business to business (B2B) markets have utilised reuse systems for a much longer period of time [19]. Pallets, crates, large bags, trolleys, and metal racks are examples. In these systems, it is much simpler to track the location of products. Making it easier to determine how often it has actually been reused. The use of reusable products in the B2B market has historically been motivated by financial incentives; however, in recent years, the sustainability aspect has also gained prominence [19].

Pieter Pot [20] is another example of a reuse system that is currently in use. This company offers food without packaging. A consumer can order food online, and it will be delivered in glass containers and bags for which they must pay a deposit. When the consumer places a subsequent order, the empty pots can be returned and the deposit will be refunded. Their goal with this system is to make it as simple as possible for consumers to use their service, as they would rather assist a large number of people in living more sustainably than a few individuals in achieving zero waste [21]. They also have a physical store in which consumers can buy packaging free products. In this case, customers will need to bring their own containers to the store to be filled. The consumer only pays for the food, and the content is weighed.

Lastly, Albert Hein (AH) has recently begun introducing reusable packaging to their customers [22]. In appendix A, a supermarket exploration of an AH store with a refill section is provided. In some XL stores, AH has incorporated a section containing refilling stations stocked with various types of dry food. The consumer has the option of purchasing reusable packaging from AH or bringing their own packaging. The consumer weighs the packaging before and after filling, so he or she will only be charged for the packaging's contents. This trial is currently being conducted in three large AH supermarkets, but if it proves to be successful, other AH supermarkets will soon join. This development demonstrates that major supermarket brands are willing to invest in a reusable system, indicating their interest.

The majority of these reuse systems share a common characteristic, which is the deposit system. This is probably because it has been demonstrated to be effective. It will significantly increase the return rate. AH is currently the only system that does not require a deposit. This is because consumers own the packaging and are not required to return it. Additionally, the AH will not be responsible for cleaning the packaging, which would significantly increase their logistics.

2.1.4 The ecosystem

Tata Steel Europe is a part of an ecosystem. Currently, this ecosystem is linear and involves numerous stakeholders, as will be explained in the following section. The ecosystem will transition from linear to circular in the future. This section also explains the stakeholders that are added to the circular ecosystem. Stakeholder analysis will explain the changes required from the linear ecosystem in order to transition to the circular system.

The current 'linear' ecosystem

This section will describe the current ecosystem in which Tata Steel Europe is a part of. Several stakeholders make up this ecosystem. These will be explained in this section. The current ecosystem is linear because it does not include reuse. The linear ecosystem is depicted in figure 8. There is still a circular component; this is the recycle loop.

There are eight important stakeholders in this linear ecosystem. Each of them have their own responsibilities, but they collaborate to provide the final product to the consumer. The thickness of the blocks in figure 8 show that the material flow in the ecosystem is currently uniform throughout all parts. All materials are recycled, incinerated, or disposed of in landfills. Recycled materials are introduced back into the linear ecosystem.

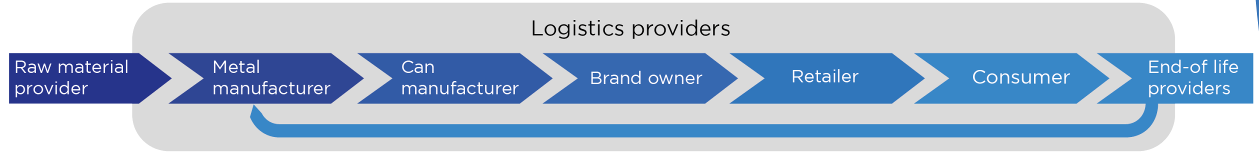


Figure 8: Linear ecosystem

Raw material provider
The raw material provider is the first stakeholder in the ecosystem. They make sure that the material is collected and shipped to the metal manufacturer, who is the client of the raw material suppliers.

Metal manufacturer
The second stakeholder in the ecosystem is the metal manufacturer; in this report, Tata Steel Europe will be referred to as the metal manufacturer. The metal manufacturer will smelt the iron ore into solid metal sheets and ship them to the can manufacturer. Customers of the metal manufacturer are can manufacturers, but in some cases brand owners as well.

Can manufacturer
The third stakeholder is the can manufacturer. They form the metal sheets into cans, which will be shipped to brand owners. The brand owners are the can manufacturer's customers.

Brand owner
The brand owner is the fourth stakeholder. This is a group of brands or a brand that fills cans with the product. Which will then be sent to the retailer. Retailer and consumer make up the brand owner's customer base. As it is also possible for the brand owner to deliver directly to consumers.

Retailer
The retailer is the fifth stakeholder. They are responsible for displaying cans in the store and selling them to consumers. The consumer who purchases the packaging is also the retailer's customer.

Consumer
The consumer is the sixth stakeholder. They are a part of the ecosystem because they purchase and use the product packaging. When the consumer has finished using the product, the can will be discarded for collection by end-of-life providers.

End-of-life providers
The seventh stakeholder is the end-of-life providers. They are a part of this ecosystem because they collect and recycle the waste generated by the products they sell (or incinerated and landfilled).

Logistics provider
The final stakeholder is the logistical provider. Because the logistic provider is involved in the steps between each stakeholder, it is depicted in figure 8 as a square in the background. They ensure that the coils, cans, and products are delivered to the correct location.

The future 'Circular' ecosystem

The current ecosystem will change over time. As there are cans that will be reused multiple times. This indicates that a portion of the ecosystem will become circular. Because not all of them participate in the actual reuse process, not all stakeholders will be involved in the circular ecosystem. For instance, the metal manufacturer does not participate in the reuse system because if they did, it would be a recycling system and not reuse. If the can manufacturer offers an option to repair partially dented cans for instance, they may be somewhat involved. The future "circular" ecosystem is depicted in figure 9. The World Economic Forum's stakeholder mapping serves as the foundation for the circular ecosystem [23].

As previously stated, not all stakeholders are involved in the reuse system. The brand owner participates in the reuse cycle by refilling the cans. The retailer participates because they restock the reused cans. The consumer is a part of the reuse system because it is the one using the product. The return/refill provider is also a component of the reuse system because they ensure that the cans can be refilled. To ensure that a reuse system is effective, there are three additional stakeholders in this ecosystem, which will be described next.

Return/refill providers
The return/refill provider is the first additional stakeholder. In collaboration with the reuse providers, this stakeholder will see to it that the return/refill procedure is handled. For instance, the return/refill providers will offer vending machines for can returns and bulk systems for can refills. They will also provide the cleaning system. In this system, the brand owner and reuse provider are the customer of the return/refill provider.

Reuse providers
The reuse provider is the second new stakeholder. This stakeholder oversees the reuse cycle and works with the return/refill provider. The brand owner, the retailer, and the return/refill provider are the reuse provider's customers. They will ensure that stakeholders communicate effectively.

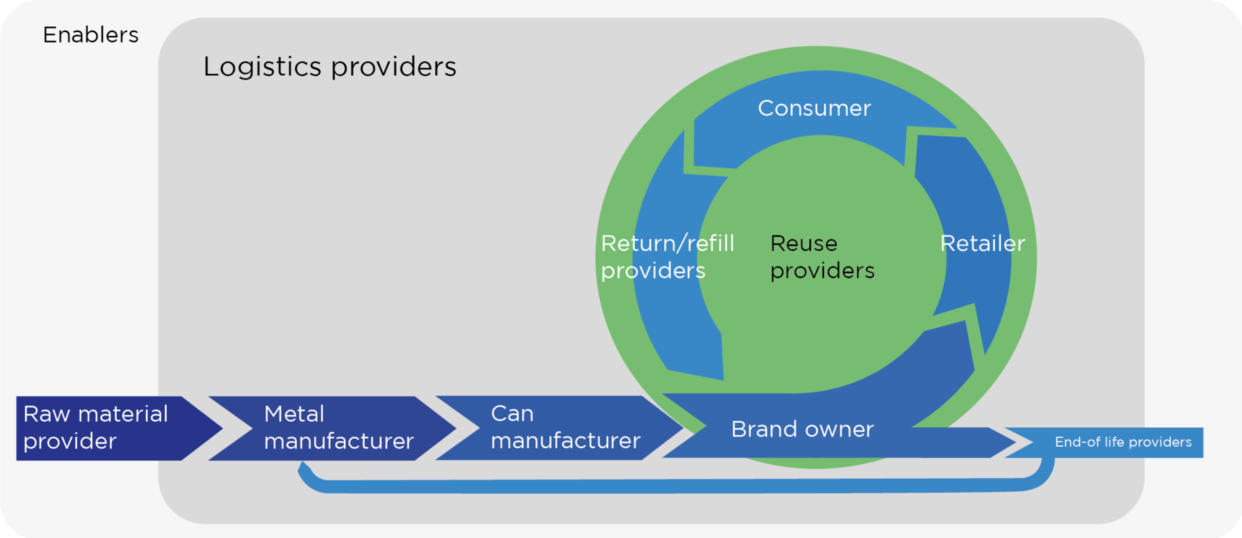


Figure 9: Circular ecosystem

Enablers
The reuse system's enablers are the final added stakeholder. They are depicted in the background because they do not actively participate in the circular ecosystem, but have an impact on it. By developing new regulations, the enablers hope to increase the frequency of reuse. The government, private investors, NGOs, etc. are the enablers.

The other stakeholders are the same as the linear model. However, their contribution to the ecosystem will change. Which will be examined in the section that follows.

2.1.5 Stakeholder analysis

In this section, both linear and circular stakeholders will be examined. This analysis determines which stakeholders are affected by a reuse system and which have the greatest influence. As a result, this may influence business case decisions.

The differences between the linear ecosystem and the circular ecosystem for each stakeholder are elaborated in Table 1. New stakeholders who are not already a part of the linear ecosystem are highlighted in the table.

As shown in table 1, the implementation of a reuse system has a negative impact on some stakeholders. Alternative strategies must be determined for these stakeholders. In order to keep them invested in a reuse system, as this is better for the environment.

To determine which stakeholders have the most influence and interest, a stakeholder map [24] has been created. A plot has been made for this purpose, with influence on one axis and interest on the other. The stakeholder analysis is shown in Figure 10. Interest and influence are dependent upon the implementation of a reuse system, the likelihood that they will invest in reuse, and the benefits to them. The position of the stakeholders has been determined based on a review of the relevant literature and discussions with colleagues.

According to the stakeholder map, the brand owner has the highest level of interest and influence, as they will be a part of the reuse system and can make decisions without consulting other stakeholders. The second most influential factor is the retailer, who decides whether or not the product will be placed in the store. The retailer is also interested because it has the potential to generate revenue from the sale of reusable packaging products. The metal manufacturer, end-of-life providers, and raw material supplier have little interest in the reuse system because it could harm their businesses. The can manufacturer is in the middle because it is semi-interested because it could provide the cans to be reused and in the middle of influence because if one can manufacturer does not want to collaborate, the brand owner or metal manufacturer will go to another who will or create their own manufacturing line. The logistic provider is interested because providing return logistics could benefit the business. The consumer is currently uninterested, but this interest will grow in the coming years as a result of climate change; their influence is significant because if they do not purchase the product, the launch will fail.

Table 1: Changes from linear to circular for each stakeholder

Stakeholder	Changes from linear ecosystem to circular ecosystem
Raw material provider	The demand for raw materials will decrease. As materials are reused more frequently than in the past. Eventually, when all materials are also recycled not as much raw material would be required.
Metal manufacturer	The demand for newly refined materials also decreases. However, unlike the raw material provided, the metal manufacturer will still be able to recycle material. They are not reliant on virgin metals because they can recycle used metals. The rate at which they produce metal will likely decrease.
Can manufacturer	The demand for new cans decreases as well. As cans are reused, for instance eight times, there are eight times fewer cans required. Expanding the portfolio of metal packaging may, however, increase the demand for new cans.
Brand owner	When reusable packaging is implemented, it is likely that the brand owner's business numbers will not change and may even increase. They will have to adapt their current customer base to reusing packaging, and consumers will have to accept a certain degree of packaging damage and a shift in brand image.
Retailer	The retailer's business numbers won't decline either. Since they will be able to sell the same quantity of products as before. However, they will need to add a section to their store for refilling or returning packaging. This necessitates additional space and personnel to manage the returned packaging. In addition, they may need to expand their home delivery options, as this increases the convenience for customers.
Consumer	For the consumer, not much needs to change. As there are numerous reuse model options. They may pay more for their initial purchase, but they save money in the long run by utilising reuse options. They also have a positive impact on the environment. One part that does changes for them is the need to store and return the packaging after they used it.
Return/refill providers	The linear model does not include this stakeholder. However, by implementing a reuse system, this stakeholder will begin to exist. This creates additional jobs and generates additional revenue.
End-of-life providers	The end-of-life provider will also have less work. Less packaging will be recycled because more is reused. However, eventually all packaging will end up there, though it may take longer than before. They will end up losing a part of their revenue as less material will end up with them.
Logistics providers	The logistics providers gain employment. They can now coordinate the logistics of reusing and returning packaging. This is advantageous for logistic providers.
Reuse providers	In the linear model, there is no reuse provider. In addition, by implementing a reuse system, this stakeholder begins to exist. This also generates employment and additional revenue streams.

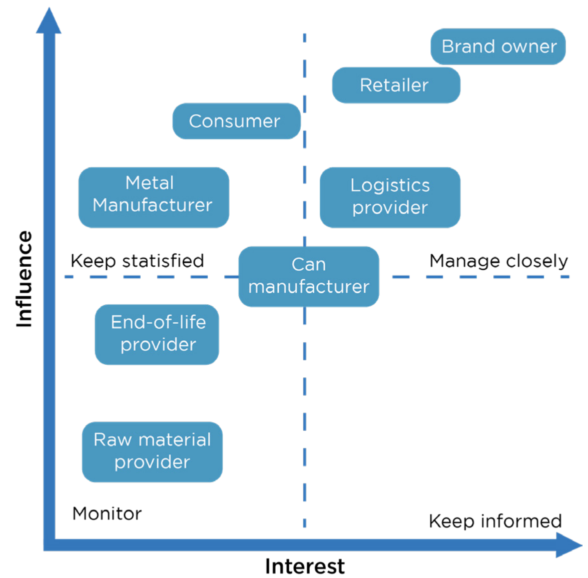


Figure 10: Stakeholder map

2.1.6 Competition analysis

This section contains the competition analysis. Since Tata Steel sells raw materials rather than finished goods, the various packaging materials will be compared. The objective is to identify Protact®'s strengths and weaknesses, as well as its position relative to other materials.

The main materials that compete with Protact® are glass, plastics, paper & paperboard, stainless steel, and aluminium (full list of packaging materials can be found in appendix B). Initially, these materials will be compared based on their known properties. These characteristics include density, magnetism, permeability, transparency, sustainability, shelf life, and strength. Steel was chosen as a comparison for Protact®, whose substrate is steel, because Protact® is excluded from GrantaEdupack [25], a programme used to compare different types of materials. The results of the material comparison are displayed in table 2, and the complete comparison is available in appendix C.

As shown in table 2, steel is the strongest material, magnetic, has a long shelf life, and has a high level of elasticity. Steel, on the other hand, is opaque and among the heaviest materials available.

Comparing the materials after they have been formed into packaging is another aspect to consider. Because this also takes logistics, recycling, and production into account. The characteristics that will be evaluated are the ease of production, contribution to the market, recycling rate, costs, and reusability of the packaging material. The results are shown in Table 3.

According to table 3, metals currently have the smallest market share, while plastics have the largest. Despite the fact that plastics have the lowest recycling rate. Steel recycles at a rate of 85%, which is comparable to that of glass and other metals. Metals are the most expensive packaging material; plastic packaging is significantly less expensive. In addition to these factors, it was interesting to consider whether the material is currently being reused. Currently, Grolsch and Loop recycle glass and various metals [26,27].

Using the results of the prior analysis, a SWOT analysis of Protact® has been performed. The SWOT analysis (Strengths, Weaknesses, Opportunities, and Threats) [24] will show which factors to concentrate on and which to ignore. The SWOT analyses will be explained next.

Table 2: Material properties comparison

	Steel (Protact®)	Stainless steel	Aluminium	Glass	Plastic	Paper & paperboard
Strength (Tensile strength/density)	Very high	Very high	High	Very low	Low	Low
Elasticity	Very high	Very high	High	Medium	Medium	Low
Fragility (fracture toughness)	Low	Very low	Low	Very high	High	High
Shelf life	Very high	Very high	Very high	Low	Very low	Very low
Permeability (UV, water and gasses)	High	Very high	High	Very high	Low	Very low
Transparency	Opaque	Opaque	Opaque	Transparent	Opaque & transparent	Opaque
Weight (density)	Very high	Very high	High	High	Low	Very low
Magnetism	Yes	Not all kinds	No	No	No	No

Table 3: Packaging comparison

	Steel (Protact®)	Stainless steel	Aluminium	Glass	Plastic	Paper & paperboard
Contribution to the market	Low	Low	Low	Very high	Very high	High
Recycling rate	Very high	Very high	Very high	Very high	Very low	High
Costs	Very high	Very high	Very high	High	Very low	Low
Reused now?	No	Yes	Yes	Yes	No	No

Internal strengths & weaknesses

Protact® has several strengths. These include the fact that it is a strong material, which makes it harder to be dented. Another factor is the material's magnetism. This facilitates the recycling of this material because it can be extracted from a pile by holding a magnet over it, which also contributes to the high recycling rates of Steel. Aside from these factors, food packaged in Protact® has a longer shelf life due to the material's low permeability. The unique selling point of the material is the fact that it is not necessary to lacquer the material as it is already coated. Rendering an expensive lacquering line at the can maker line unnecessary. Which also reduces the amount of space required to produce packaging.

Protact® also has a variety of weaknesses. As steel is susceptible to corrosion, the exposed areas of the material may begin to corrode upon contact with liquid. The material is more expensive than uncoated material. In addition, the material is susceptible to denting, which may result in unattractive visual effects. The material is heavier compared to plastic alternatives, but the difference is not significant when compared to glass and other metals. Currently, Protact® is not being reused, so there are no known errors or trails associated with the material.

External opportunities & threats

Opportunities for Protact® include the potential to increase the lifetime of packaging material, as compared to currently recycled materials such as glass and thick plastics. Protact® is more environmentally friendly than plastics because it can be easily recycled. Finally, Protact® could be used in new market segments that would not have been possible with lacquered materials.

Then, there are multiple threats to the material. One of these is a more cost-effective, reusable material that can be used for packaging. Another risk is if the material is not accepted by the market because it has not yet been introduced as reusable. As the material can be reused multiple times, the likelihood of visible dents increases, which may cause consumers to choose an alternative product. Another danger is the fact that there are restrictions on the types of cleaning supplies that can be used. Due to the fact that Protact® is a combination of steel and plastics, certain cleaning agents may alter the material's composition or adhesion. The final threat is that can manufacturers already own lacquering lines and do not wish to abandon them. In that case, Protact® will not be implemented.

This comparison study demonstrates that every material has benefits and drawbacks. Protact® is not a material with only advantages. This information will be incorporated into the business plan for the reusable Protact® packaging.

2.2 Use and User research

This section contains the findings of research conducted on the use and users of the reuse system. In this study, the users have been divided into two groups. Consumers, who will use the packaging, come first. The other group is the linear ecosystem as described in section 2.1.4. It was determined that consumer demands and desires would differ from those of businesses, and by separating them, these distinctions are made clear. This research was conducted to identify the barriers to adopting a reuse system and to find reasons to keep consumers and businesses committed even when it is not in their best interests.

2.2.1 Urge to reuse

For a very long time, when creating or consuming a product, packaging was the least of your concerns. There were no consequences, and consumers appreciated the convenience. The packaging ensured that the food (or other packaged products) they purchased was easily transported home, had a longer shelf life, and could be stored more easily [28]. Above all, the consumer could simply discard the packaging after use without giving it a second thought, and they could do the same thing again and again. This has resulted in significant accumulations of plastic waste, as nearly every person on the planet shares this view. In 2019, there were 32.2 million tonnes of plastic waste [29]. Globally, only 9% of waste is recycled, and 22% is mismanaged. This mismanagement of waste has resulted in a number of health problems for the current population. Plastic has contaminated oceans, rivers, and marine life [30,31]. Without changes, plastic waste could triple by 2040 [32].

In addition to ocean pollution, improperly managed plastic waste contributes to micro and nano plastics. Which are essentially very small plastic particles found in the ocean and in the food we eat (because we eat fish and other animals that have come into contact with these aquatic sources) [33,34]. The impact they have on public health is largely unknown, which could lead to even greater problems in the future [13]. Millions of people around the world are affected by disease, drought, and air pollution as a result of improper waste management [35].

The government is also becoming more aware of plastic issues and has decided to drastically reduce single-use plastic use. The EU's Directive on Single-Use Plastics [36] demonstrates their intent to combat plastic pollution and marine debris. This directive prohibits single-use items such as straws, cotton buds, cutlery, and balloon sticks. These items were viewed as easily exchangeable for alternatives that could be reused. The EU also wants all packaging on the EU market to be economically reusable or recyclable by 2030, with at least 10% being reusable [34].

Due to these factors, consumers have begun requesting sustainable packaging from brands. Which is yet another reason for businesses to begin the plastic change. If they do not change soon, they will lose paying customers to other competitors who will [37].

2.2.2 Consumer research

Consumer research has been conducted to determine the barriers and advantages consumers face when reusing packaging. This research exists of literature research. This decision was made because there is already a great amount of information available about consumer preferences; therefore, there is no reason to repeat the same research. Appendix D contains the full results of the consumer research. In this section the most important insights will be explained.

Since consumers have become more environmentally conscious over the past few years [23,38,39,40,41], their attitudes towards sustainable packaging have shifted. The ocean pollution and other environmental problems have been linked to unsustainable packaging, prompting a rethinking of packaging [23,38,42,43]. Thus, consumer demand for more sustainable packaging has increased, and brands have responded [23,38].

However, before consumers begin to adopt reusable systems, a number of factors must be taken into account. As they would otherwise discourage them from using the reuse system.

Price [16,38,43,44,45,46,51]
One of the most significant aspects of reusable products is the price of the product, as well as the potential increase in price they would incur if they reused the packaging. Numerous studies have demonstrated that consumers do not wish to pay a premium for reusable packaging; therefore, maintaining the same price as the conventional alternative is the best course of action [44,47]. Consumers are willing to pay more for reusable packaging, according to research conducted by Trivium [38]. However, when looking at the actual number, the majority of respondents (approximately 54%) do not want to pay more or only a small percentage. Bad pricing policies also have an impact on consumers, as some businesses have demonstrated in the past that charging a premium for reusable packaging is not the best course of action [51].

Quality [16,23,42,43,45,46,47,51]
When it comes to reuse systems, quality is the second most important factor. Consumers require reusable packaging to be durable for an extended period of time; when this is not the case, the packaging is perceived as being of low quality, and consumers are unlikely to purchase it again [42,43]. With quality comes packaging safety; the packaging must be in excellent condition even after multiple uses so that it does not pose a hazard to consumers [23]. Additionally, damage to the packaging discourages consumers from bringing it home, which lowers brand perception [47].

Inconvenience [16,23,45,47,51]
The inconvenience is another significant factor in consumer adoption of reuse systems. It's about how far they would have to travel to purchase and refill their reusable packaging. Moreover, the convenience with which they can refill the packaging. In addition, consumers fear forgetting the packaging at home or at all, which would result in the forfeiture of the paid deposit [47].

Hygienic issues [16,42,44,45,47,51]
Hygienic concerns are also regarded as crucial. Many consumers consider repurposed items to be less hygienic [44,47]. This is due to the fact that reused items are associated with previous consumers and that consumers are unaware of what happened to the packaging. For consumer-owned reusable packaging, it is crucial that the packaging is simple to clean [42].

Ineffective communication [16,45,51]
Ineffective communication can make or break a reusable product [51]. Which could result in consumers discarding the packaging after a single use, in which case the packaging is even worse for the environment than the single-use alternative.

Risk of unavailability of refills [16,45,51]
The lack of refills also influences consumer decisions. Even if the consumer has reached the point where they are ready to refill the container and the refill is not available, they will have to choose another option to obtain the product they desire.

Perception of consumers [48,49]
Lastly, their behaviour is influenced by their perception of reusing packaging. Even though it is better for the environment to reuse packaging, consumers who are unaware of the issue may not recognise it. Awareness, motives, and social behaviour can influence a consumer's decision to reuse packaging [42,45,50].

In addition to these barriers, there are a number of benefits for consumers when they reuse packaging. This feature would encourage consumers to recycle their packaging more frequently.

Decreased environmental pollution [47,51,52]
Reusable packaging reduces the amount of wasteful packaging materials. They have a direct impact on how much waste is improperly managed. This provides consumers with a sense of well-being, enhancing their sense of self-worth. However, the feel-good factor alone is not enough to convince consumers to reuse packaging [51]. This is also supported by the fact that consumers increasingly view packaging eco-friendliness as an important factor in their decision-making [39,40,41].

Reduced costs [44,47,51,52]
On the other hand, well-thought-out pricing strategies may increase the use of reusable packaging. Unlike the poor pricing strategy previously mentioned. When reusable packaging is priced comparably or less expensive, consumers are more likely to use it [44,47].

Price incentives [47,51,52]
Price incentives are another factor that might have a positive impact on consumers' reuse behaviours. Utilizing deposit systems or rewards programmes. For multiple uses of reusable packaging, consumers receive rewards. Consumers are also more likely to return packaging when price incentives are used [51,53].

Increased customization [23,51,52]
Increased personalization have a positive effect on consumer behaviour because reusable packaging has a longer shelf life than standard packaging. The packaging for each product can be customised by the manufacturer. Which can result in increased functionality in the packaging, thereby providing consumers with additional benefits.

Convenience [51,52]
Reusable packaging may also be associated with convenience. As there are also systems that deliver products to your doorstep. In this case, consumers need not even leave their homes to have a positive impact on the environment.

Increasing consumer awareness of ocean pollution has also been shown to increase their willingness to reuse packaging [30,54]. Consumers are also demonstrating their awareness by stating that they have been looking for recycling logos more frequently in recent years [38,55]. However, another study indicates that recycling logos are less significant than the material from which the packaging is made, as consumers are typically more knowledgeable about material sustainability than about specific recycling logos [44,56].

Consumers also demonstrate that they are currently reusing packaging [57]. However, these are their own packaging, not that of the supermarket. Jars and pots, for instance. This study also demonstrates that male and female consumers behave differently when it comes to reuse. Female consumers recycle packaging more frequently than male consumers.

Consumers are also willing to reuse grocery packaging, according to research [47].

Customer journeys

Customer journeys are created to determine which reuse system is optimal for the customer. These are based on the findings of the literature review. Five customer journeys were made. One for the current linear packaging and four for each reuse system identified by the Ellen MacArthur Foundation [42]. This section will summarise the outcomes; appendix E contains the complete customer journeys and their explanations.

In comparison to the current linear packaging, the customer journeys indicate that the reuse system return from home would be the best option. Because, like the linear system, this reuse system requires little consumer effort. However, after speaking with Loop, it was discovered that a return from home system provided by an external organisation is not particularly effective. As a result, a return from home system would be most effective when combined with online grocery shopping. The return on the go option would be ideal if customers do not order their groceries online. The consumer is responsible for purchasing and eventually disposing of the packaging for the refill at home and refill-on-the-go options of the reuse system. Although these systems are initially more expensive, which may deter potential customers, they will save them money over time.

2.2.3 Ecosystem research

The barriers and benefits of the ecosystem stakeholders have been identified through research. This study will combine qualitative and quantitative approaches. The literature review will be used to determine what information is already available about the specific aspects of this research. Quantitative research will be conducted to determine the capabilities of the ecosystem, as well as the reasons why they do not currently use such a system and why they may feel the need to do so.

Literature review

Eight stakeholder groups and one enabler for reuse systems make up the reusable packaging ecosystem [23]. Materials providers, manufacturers, forward logistics providers, sales channels, users, return/refill providers, end-of-life managers, and reuse providers are the eight groups. Enabling parties include the government and private investors [23,58]. As stated in the ecosystem section. This study will identify both barriers and benefits for the ecosystem.

According to the research, there are a number of barriers to overcome. The challenges that the ecosystem must overcome are greater than themselves, and as a result, they must collaborate to create a functional system [23,47,58]. The following section will describe each obstacle.

Hygiene issues [51,59]
The first difficulty is maintaining the cleanliness of reusable systems, particularly bulk systems. To ensure proper operation, the government has established industry standards (such as ISO 22000 Food Safety Management and Regulation (EC) No 178/2002). This standard requires retailers to conduct risk assessments in order to determine effective, proportionate, and targeted measures or other actions to protect the health of consumers.

Change in business model [13,58]
To provide reusable packaging, a system change is necessary. The current linear model only permits a one-way journey for packaging [13]. To create a circular model, a change will be required. Including reverse logistics [23]. Reverse logistics will necessitate collaboration between logistics providers, sales channels, and return/refill providers.

Brand image [23,51]
A crucial component of selling a product is the brand image. When a product's appearance is altered to make it compatible with a reusable system, the brand's reputation may shift. This may pose a threat to the brand image of a particular product, and its manufacturers are concerned that sales will suffer as a result.

Traceability issues [51,58,60]
Traceability is a potential additional issue. It is impossible to determine how many cycles have occurred because reusable packaging cannot be tracked. Aside from that, it is impossible to determine where a packaging was lost or broken, which could cause trust issues in the ecosystem [58].

Need to collaborate [23]
Lastly, the need for collaboration with other businesses may be a barrier to adopting reusable packaging. As previously stated, one business will not be able to implement a reusable system on its own.

A circular system, which enables the use of reusable packaging, has a number of benefits in addition to these barriers.

Consumer loyalty [23,51]
One benefit is increased consumer loyalty. As consumers refill packaging, the likelihood of them returning and refilling with the same product rises, thereby fostering brand loyalty over time.

Modern technology [23,51,58]
By incorporating modern technology into reusable packaging, the opportunity to track the packaging as it is used is created. This means that it is now possible to determine the packaging's durability and number of cycles [61]. The ecosystem becomes more transparent as a result. Which could facilitate business collaboration [62].

Consumer perception of brand, in regard to sustainability [16]
When the brand must implement reusable packaging, the perception of the brand will change. As consumer awareness grows, they are constantly seeking more sustainable alternatives, and when a brand responds to this question, it increases the positive perception of that brand.

Potential business opportunity [42]
It is anticipated that the global market for returnable and reusable packaging will increase by $10 billion [42]. To obtain this advantage from reusable packaging, it is essential to minimise unintended negative effects.

Decreased amount of packaging waste [42]
Lastly, by implementing a reuse system, packaging waste will be reduced. This will result in less waste entering aquatic ecosystems and fewer health problems in the future.

In addition to these benefits, accepting reusable systems provides opportunities for certain stakeholders [23]. It is possible for manufacturers to lease their packaging rather than sell it to their customers, allowing them to continue generating revenue even when the demand for new packaging declines. The opportunity for waste companies is in implementing large-scale reuse systems. They are able to implement a reuse system because they currently own the collection and separation of waste. Last but not least, system enablers can provide the transportation tools necessary for reuse systems.

For a reuse system to be successful, the following factors must be taken into account [23]. It should include a shared reuse system with centralised infrastructure to deliver reusable on a larger scale. The consumer experience should be superior to disposables. By incorporating new technologies, more services with added value should be offered. The regulation should incentivize reuse systems and provide reuse targets to the ecosystem. As they switch from disposables to reusables, there must also be a cultural shift. Lastly, the effectiveness of the reuse system should be demonstrated. There should be a standardised reporting format for reuse system accounting.

Interviews

Prior to conducting interviews, it was necessary to decide whether to perform qualitative or quantitative research. Quantitative research is typically used to test specific theories and hypotheses, whereas qualitative research is typically used to comprehend reasoning, thoughts, and experiences [63]. Because of this, quantitative research was chosen for this project. Knowing why the stakeholders want particular things is much more important than just seeing a number on a screen. During quantitative research, it is crucial to delve deeper into the rationale underlying their decisions and ideas.

There are also a few options for the type of quantitative research. Specifically, structured, semi-structured, unstructured, and focus group interviews [64]. In structured interviews, the order and questions are predetermined. There are no predetermined questions or order in unstructured interviews. In semi-structured interviews, questions are asked, but not all of them must be answered, and there is room for interpretation. The final option is focus groups, in which you pose questions to multiple people at once, thereby gaining an understanding of the opinions of multiple people simultaneously. Interviews with a semi-structured format were selected for this study. This is due to the fact that this type of interview leaves room for interpretation. There must be room in the interview to accommodate important information that occasionally comes up without being asked. In contrast to unstructured interviews, it is still possible to steer the conversation in a direction that is beneficial to the research in semi-structured interviews.

During the course of this project, a total of six interviews were conducted. Four were with brand owners and two were with can manufacturers. The complete responses to the interviews can be found in appendix F. In this section, a summary of the responses will be provided, along with the frequency with which each response was provided. To create structure while asking the questions, the questions were divided into four sections. These are the brand, the reuse system, the product, and behaviour.

Brand

Do you currently own/market any reusable packaging? Why/why not? (n=6)
5 out of 6 have made/sold reusable packaging, business owned and consumer owned taken into account.

Do you think it is important to have reusable packaging? (n=2)
Both believe that having reusable packaging is crucial.

What are the biggest challenges your brand would face implementing a reusable packaging? (n=6)
Hygiene/food safety, logistics costs, counterfeiting (selling inexpensive products in expensive packaging for a premium), brand recognition, convenience, and reuse systems are still in development. The sales numbers are low (but are expected to increase in the future), tracking packaging.

When you are implementing reusable packaging which aspects are the most important for your brand? (n=4)
Hygiene, food safety, logistic, convenience, brand recognition and counterfeit

Are your retailers open to adding reusable packaging into their stores? Why/why not? (n=3)
The retailers are receptive to or already use reusable packaging in their stores.

What are the benefits of implementing reusable packaging to your business? (n=2)
For marketing and environmental reasons. However, as stated by can manufacturers, brand owners reap the majority of the benefits.

What are the disadvantaged of implementing reusable packaging? (n=2)
Fewer products sold; coating line is no longer required (in case of Protact®). Not much will change for smaller can manufacturers.

Reuse system

Would your brand be willing to invest in a reusable packaging and system? (n=5)
All five have stated that the brand would be willing to invest. Three out of five respondents indicate that they require return on investment within a reasonable timeframe.

Do you have the capability to provide reverse logistics for the reusable packaging? (n=4)
None of the brand owners are able to provide reverse logistics.

Logistic wise would it be necessary for the return packaging to be able to be stacked together? (n=4)
Three out of four say it is necessary, the other one stated it is not necessary but from a sustainable perspective it might be.

Which reuse system would be more beneficial to your retailers/your brand? (n=3)
There was no specific answer. However, the four options where the brand owner owns the packaging are the most intriguing (these are refill on the go and return on the go).

Product

Would it be beneficial to your brand to include tracing (using RFID for example) into the reusable packaging? Why? (n=4)
All four agree that this is advantageous because it will provide businesses and consumers with greater packaging insight.

Do you think the price of a reusable packaging will be higher or lower compared to the single-use alternative? (n=3)
Answers are divided (higher, lower, or the same amount), and prices are currently higher. Tracing may influence this. Priority should be given to convenience.

Would you rather prefer one universal design for several products, but with different labelling, or for every product a different design? Why? (n=4)
Considering sustainability, a universal design would be preferable. Different designs for all products would be preferable from a marketing standpoint. To prevent deception, there should at least be some differentiation between product categories.

Behaviour

Is it important for your consumers to have reusable packaging? (n=3)
Both agree that interest must continue to rise. Currently, consumers are unaware of the necessity.

What do you think is the biggest hurdle for your consumers to use reusable packaging? (n=3)
Behaviour change required, hygiene, convenience, price.

Do you think consumers would accept imperfect (appearance) packaging when it is reusable? (n=4)
Now, not at all. When dents are concealed, for instance, or when the consumer becomes accustomed to it, this may not be an issue.

Acceptance dents (n=3)
None of the respondents would tolerate dents unless they could be concealed.

Comparing the responses from the literature review and the interview reveals that they are comparable. Particularly the aspects that were mentioned. Such as hygiene, logistics, brand image, and tracking. It demonstrates that there is a high likelihood that these aspects are accurate. The interviewees' additional responses will be taken into account when designing the packaging.

2.2.4 SWOT-analysis stakeholders

Using the data gathered from the literature review and interviews, a SWOT analysis has been developed for each stakeholder. The SWOT-analysis can be found in appendix J. The SWOT analysis has been conducted for each stakeholder to provide an overview of their strengths, weaknesses, opportunities, and threats. The data obtained from this analysis will be incorporated into the creation of the business case. To attempt to maintain all stakeholders' interest in the reuse system/packaging.

2.3 Technology research

This section displays all technology research performed. These include production techniques, legislation, the washing system, patent research, and material research. These studies are conducted to determine the packaging production and design possibilities. All of this research may limit important design freedom options. These restrictions will ensure that the packaging can be manufactured, cleaned, and introduced to the market.

2.3.1 Production techniques

There are a few production techniques that are currently used with Protact®; additional techniques that may be of interest are also explored and can be found in appendix G. The techniques most commonly used will be examined. Aside from this, two types of cans are produced using distinct methods. These are two-piece cans (2P cans) and three-piece cans (3P cans), and the difference between the two will be explained because it may affect the final decision for either one.

The 2P can, as its name suggests, consists of two pieces. This ensures that the packaging is highly production efficient, has excellent sealing, is simpler to manufacture, and has no seam [68,69]. The limitations of 2P cans include limited material options, increased waste material, and the need for specialised technologies, equipment, and dies. [68]. The 2P can dominates the beverage industry.

The 3P can consists of three components: the body, the lid, and the end. The 3P cans are rigid, facilitate the production of larger sizes, are adaptable to various can shapes, require less raw material, and can accommodate a variety of material types. The disadvantages of 3P cans are that they have more potential weak points, such as seams and connections between the three pieces [68]. The majority of food industry cans are 3P cans, but 2P cans are also used.

2P cans production techniques

There are two distinct production methods used for 2P cans. They are known as draw and redraw (DRD) and drawn and wall-ironed (DWI). Both methods begin with a first blank and a draw. The subsequent steps are distinct. Each of the two techniques' individual steps will be described in greater detail, along with their rationale.

DRD

DRD ensures uniform wall thickness throughout the can [67]. Several drawing steps are required to ensure that the wall thickness remains constant; the DRD production technique is depicted in figure 11. Following the creation of the blank, the first draw yields a cup with a diameter larger than the required diameter.

This is done to ensure uniform wall thickness. When redrawing the can's diameter and height, there are multiple steps involved. The number of steps depends on the height-diameter ratio; in some, redrawing is not required, while in others, it is required three times, for instance. These are the steps in the DRD manufacturing process:

Coils – Sheets –Blank – 1st draw (with greater diameter) – 2nd draw (with smaller diameter and more height) – 3th draw (with final height and flanged) – 4th draw (with final height and diameter and with indents in bottom) – 5th adding of beads (or other complications) (if necessary) – test are performed to see if there are no imperfections – cans are sent to filling line [65]. At filling line, the cans are seamed by the filler.

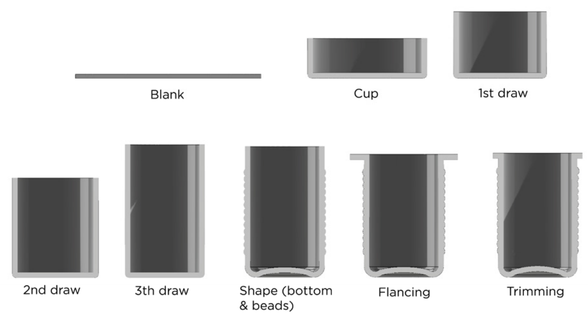


Figure 11: Illustration DRD steps [65]

DWI

As previously stated, DWI is comparable to DRD. After the second draw, the walls are ironed in this technique. This occurs in two stages [69], as shown in figure 12. During the ironing process, the thickness of the can walls is decreased. The strength of the walls is decreased as a result of the weight reduction. For beverage and food cans, this method is frequently employed. The following are the steps in the DWI manufacturing process:

Coils – Sheets – blanks – drawing (creating a cup) – Ironing the walls (to create preferred height) – Edges are trimmed – the can is washed and dried – surface is coated/printed – through oven (to dry and bake the can) – The edge is flanged – test are performed to see if there are no imperfections – cans are send to filling line [66]. At filling line, the cans are seamed by the filler.

This production method is typically used for beverage and food cans because the content also gives the can strength. Without its contents, it is much easier to dent the can; therefore, beads are added to food canisters to increase the strength of the walls. Since the wall thickness is reduced, less material is required to produce this can, making it more environmentally friendly than, for instance, the DRD production method.

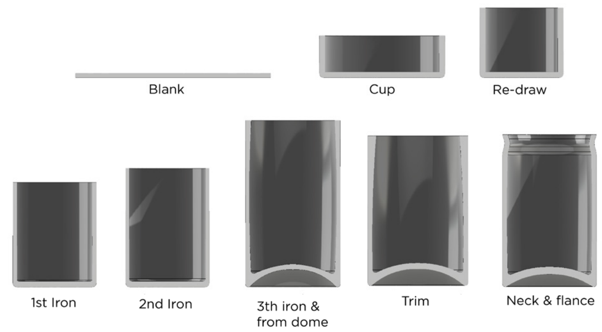


Figure 12: Illustration DWI steps [66]

3P cans production technique

Figure 13 depicts the only method of manufacturing 3P cans. However, this method can produce a variety of results. Similar to the DRD cans, the wall thickness of the 3P cans is uniform. However, as previously stated, the 3P cans are welded together, creating weak points. The following are the manufacturing steps for 3P cans:

Coils – Sheets – blanks – rounding – welding – weld protection – curing of weld protection – edges are flanged – bottom is applied – beads are added – test are performed to see if there are any imperfections – the cans are sent to filling line. At filling line, the cans are seamed by the filler.

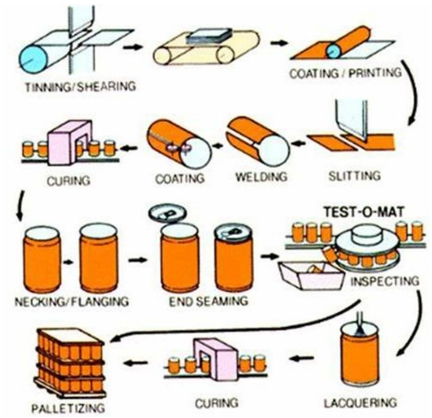


Figure 13: Illustration 3P steps [67]

2.3.2 Legislation research

This section will discuss legislation relating to reusable packaging. The reviewed legislation also includes a new packaging and packaging waste regulation. Directive (EU) No. 94/62/EC served as the predecessor to this regulation [74]. Since the member states could choose whether or not to comply with it voluntarily, this change was necessary. However, now each member state will be required to comply.

Reusable packaging must adhere to a number of requirements, according to this new regulation (EU) No 2022/0396 [80]. One of these is that the reusable packaging must be capable of being emptied or unloaded without damage.

The packaging should also be designed, conceived, and distributed with the intention of being reused or refilled. Appendix H contains additional requirements from this and other regulation listed in this section.

In addition to this regulation, there are a few other regulations/directives that must be considered during this project. Sustainable and reusable packaging are addressed by Directive (EU) 2008/98/EC [70]. It stipulates that packaging should be reused, recyclable, or recovered, and should use the least amount of material possible. Reusable packaging must meet criteria for recovery after it is no longer needed, be suitable for reuse, and be manufactured in accordance with labour laws.

The besluit beheer verpakkingen 2014 [77] is another law that applies to the Netherlands. This regulation is in line with the EU, with the exception that it requires a deposit on cans with a capacity of less than 3 litres beginning in 2024 [78]. The new regulation also states that cans with a capacity of more than 3 litres will also require a deposit, but this is not yet in effect.

Table 4 contains a list of all applicable laws and regulations for this project, along with a brief description of each. The regulations cover food labelling, food-contact materials, sustainability, and packaging production. The requirements from these regulations will be added to the list of requirements.

In addition to regulations governing reuse systems and reusable packaging, there are also regulations governing responsibility. Currently, consumers are solely responsible for recycling materials after they have been used. Overuse of materials, environmental materials, and a lack of funding made it impossible to recycle all of the used materials. By the end of 2024, Directive (EU) No. 94/62/EC [74] will put an end to this practise and shift the responsibility for recycling to the producer. They will be required to pay a set amount for each tonne of waste they produce. This can be used to collect and recycle the material.

Table 4: Important regulation when designing packaging

Regulation/Directive	Short explanation
Directive (EU) 2008/98/EC [70]	This directive is about reducing the waste created. By encouraging reuse and recycling, and minimizing landfilling.
Regulation (EU) No 1169/2011 [71]	This regulation is about providing sufficient information on the labelling of food packaging.
Regulation (EU) No 2018/775 [72]	This regulation is about providing indications of country of origin of the primary ingredient used in the packaging.
Regulation (EC) No 1935/2004 [73]	This regulation is about general safety principles of food contact materials.
Directive (EU) 94/62/EC [74]	This directive is about the management of packaging waste. To decrease the amount of packaging waste generated every year.
Directive (EU) 2018/852 [75]	This directive is a supplement to directive (EU) 94/62/EC. The intention of this directive is to better guide towards a circular economy.
Regulation (EC) No 2023/2006 [76]	This regulation is about good manufacturing practices for materials that come into contact with food.
Besluit beheer verpakkingen 2014 [77,78,79]	This regulation is specifically for the Netherlands. It shows the regulations that are true for the Netherlands
Regulation (EU) No 2022/0396 (COD) [80]	This is the newest version of the packaging and packaging waste regulation. It is has not been implemented yet but will be considered when designing the new packaging.

2.3.3 Washing system research

This section will examine the washing system that will be used for the reusable packaging system. Currently, there is no prefabricated system for reusable packaging. Loop has developed its own system, which will be described at the ending of this section. In this section, the washing system and drying system options will be explained. For each of these, the most important aspect of the washing system is that the packaging is clean and free of bacteria.

Typically, industrial washing machines consist of three phases. These are the pre-wash, general wash, and rinse wash. The purpose of the pre-wash is to remove large particles of dirt. The general wash should remove any remaining dirt and kill bacteria. In most cases, the final rinse is performed with water or a cleaning agent that accelerates the drying process. During the pre-wash, the temperature may reach 35 to 40 degrees [81,82], while the general wash must be at least 60 degrees to kill bacteria [83]. The rinse must be at least 80 degrees, as bacteria begin to die at temperatures above 74 degrees [84].

During the washing procedure, a variety of cleaning agents could be utilised. Washing solutions and rinse aids are the two categories. As these two employ various chemicals.

Sodium hydroxide is the most common chemical used in dishwashing solutions [85,86,87,88,89,90]. Which has excellent grease and stain removal properties. There was also a source that combined trisodium nitrilotriacetate and disodium metasilicate [89].

Rinse aids are used to prevent water from forming droplets and instead allowing it to drain from the surface. Fatty alcohol alkoxylate is typically used as a rinse aid [86,91,92]. There were also sources that employed sodium xylene sulfonate surfactant [93] and citric acid, ethanol, and C8-10 D-glucoside [92]. After these chemicals are used, they are removed using water. In addition to posing potential health risks, these chemicals must be completely removed.

For the drying process, it is essential that all water droplets have evaporated. As this could potentially affect the food that will be placed inside. To ensure that all water droplets are eliminated, the packaging could be heated to a temperature of up to 260 degrees in an oven [94]. However, this may not be necessary because standard household washing machines incorporate air drying. The water heats the plates, and when it comes into contact with cooler air, it evaporates on its own. This could also be used in industrial machinery; however, it is impossible to determine whether every water droplet has evaporated (for this a sensor could be used).

There is a hygiene code [95] for the washing and cleaning process that is used to determine whether a washing process meets its standard. The following risk factors are indicated by this code:

- The presence of contaminants
- insufficient removal of contaminants during preparations
- insufficient inactivation of micro-organisms and toxins during preparations
- contaminating products with micro-organisms, chemicals and/or other foreign components during storage, handling and preparation of products
- the occurrence of growth of micro-organisms and/or formation of toxins in products during storage, handling and preparation
- the occurrence of chemical changes in products/material during storage, handling and preparation.

This hygiene code must be considered when examining the washing and drying system utilised for the reusable packaging.

2.3.4 Patent research

This section contains patent research. This research was conducted to determine what types of reusable packaging patents are available on the market. This may provide valuable insights into the current market, such as what will be sold and which techniques are no longer applicable. Appendix K contains the complete patent research. There were only a few patents that were applicable to the project.

One of these relates to a re-usable candle container (US2022316695A1) [96]. This patent is interesting because it utilises the original candle refill system. Therefore, the outer packaging is reused multiple times while the inner packaging is replaced every so often. This is another option that could be considered for this project.

There were also a few additional patents of interest [97,98,99,100,101]. These were all related to reusability and related techniques, such as RFID tags. Currently, there are no patents pertaining specifically to reusable metal packaging. This is advantageous because it indicates that there are no restrictions imposed from that end during the project.

2.3.5 Material research

Material research was the last research performed. This was necessary in order to determine whether Protact® would be a suitable material for reusable packaging. This section will elaborate on the reuse cycle, the research tests performed on the material, and the results.

The reuse cycle and critical points will be examined initially. To accomplish this, the entire life cycle of reusable packaging must be taken into account. The life cycle of a reusable packaging is shown in figure 14.

This figure illustrates the entire process for creating and utilising reusable packaging. Therefore, the process begins with the extraction of raw materials and concludes with recycling. The packaging can be damaged from the packaging manufacturing process, as this is where the packaging is created. To ensure that the reusable packaging can withstand its entire life cycle, a number of critical points must be analysed. To determine which points these are, each step from packaging production to food insertion is evaluated. Appendix L contains a list of all the steps performed during these phases. Next, the most crucial steps will be described.

Transportation
Transportation is the first important step. During the reuse cycle, the packaging is moved numerous times. During transport, the packaging will be subjected to both drops and vibrations. It is crucial that the package does not become excessively dented, as this would prevent it from being sold.

Handling
Second in importance is handling. This step occurs after the customer has purchased the product. The customer will empty the packaging during this step. This can be accomplished, for instance, with a spoon or knife. This could cause harm to the interior and exterior of the packaging. It is essential that the packaging is scratch-resistant to a certain degree .

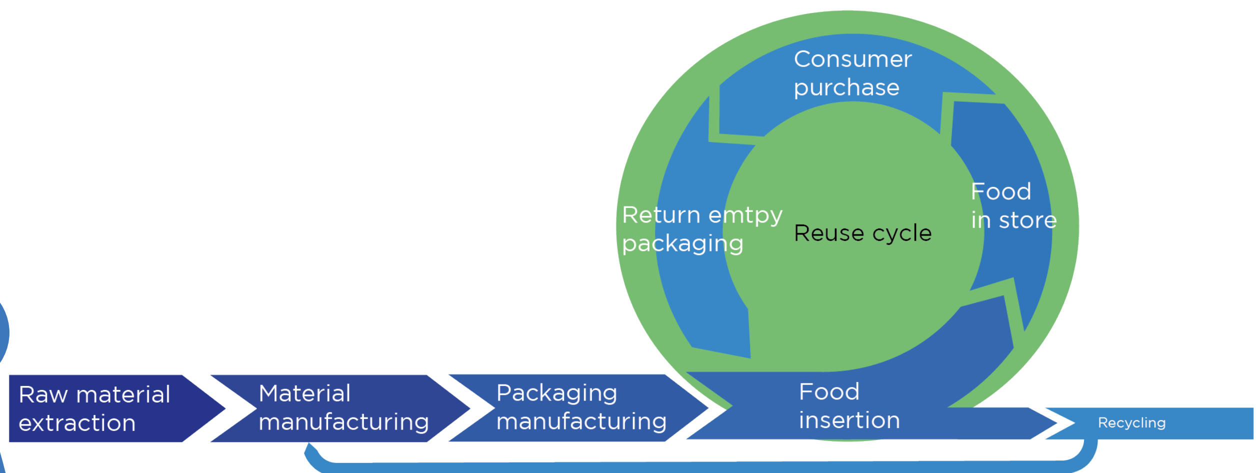


Figure 14: Life cycle with reuse cycle

Industrial washing (and drying)
Industrial washing and drying is another important step in the reuse cycle. The packaging will be exposed to water and high temperatures during this step. It is essential that this step has no effect on the material while still producing a clean product. During this test, washing detergents and temperature settings will be evaluated.

Closures
Closure of the packaging is the final crucial step. Throughout its lifetime, the reusable packaging must be capable of being closed and opened multiple times. It is crucial that this closure has no effect on Protact®'s coating layer.

With the addition of microscopic research, these four factors have been used to develop material research test setups. Research at the microscopic level provides valuable information about the material's limitations.

In order to determine the suitability of Protact® as a material for reusable packaging, two coating options will be compared: Protact® PET and Protact® PP. Additionally, tests will be conducted with different substrate thicknesses to determine the effect of drops on material thickness.

The following section will describe the tests conducted and their most significant outcomes. Appendix M contains information about the general setup used for each material research test, including the types of cans and materials used.

Microscopic research
The first research conducted was microscopic research; the complete results are shown in appendix N. This research was conducted to determine the limits of the material, namely its melting temperature and resistance to water. Various techniques were used to examine these limitations so that the results could be compared. The methods utilised are Raman spectroscopy [102], Fourier-transform infrared (FT-IR), differential scanning calorimetry (DSC), energy-dispersive X-ray (EDX), and light optical microscope (LOM). The appendix, provides additional information about the specific techniques.

Prior to conducting tests for heat or water resistance, it was essential to determine the composition of the coatings. This test utilised both Raman and FT-IR. Both methods proved that the materials in question are PET and PP. Raman could also be used to determine the material's thickness. The PP layer is approximately 40 Qm thick, whereas the PET layer is approximately 25 Qm thick.

The subsequent step involved determining the melting temperature. Raman spectroscopy and DSC were both utilised for these tests. According to Raman measurements, PET melts between 210 and 260 degrees, while PP melts at approximately 165 degrees. However, PET glass transition point is also significant for the result (with PP this is below 0 degrees so it does not affect the material above room temperature anymore). Once it exceeds the glass temperature, the molecules begin to move more quickly, which could result in the coating peeling away from the edges. This is estimated to be at 75 degrees. The DSC reveals a melting trajectory for PET between 220 and 250 degrees, whereas Raman reveals that the melting point of PP is identical to the results of the DSC. It is possible that the air in which the tests were conducted contributed to the difference in PET melting trajectory. The Raman tests were performed with air, while the DSC tests were conducted with nitrogen. Because PET responds to water molecules in air, the trajectory may occur earlier than predicted by the DSC. There is no effect on PP.

Using a light optical microscope, the Raman test samples were then imaged. When samples of PET were heated to 110 degrees, it was evident that the material's edges had released and that wrinkles had formed. The PP samples were not affected by this. After observing this phenomenon, it became necessary to determine if these wrinkles would cause corrosion of the steel substrate. The EDX was used to determine whether or not these wrinkles presented a problem. This has shown that there are no cracks or holes in the folds, indicating that the metal cannot corrode as a result. Nonetheless, this could still be a result of the material that has released from the edges. Therefore, this must be considered in future research.

Transportation

The transportation test existed out of drop tests, appendix O show the complete test. During the drop tests, the cans were dropped from various heights; 0.5m, 1m, and 1.5m. The objective of the drop tests was to distinguish between thick and thin substrates in terms of dent deformation. Aside from that, it is also used to determine where the majority of dents occur, which can be taken into account during the design phase.

The droptests were comprised of 18 distinct tests. Half of the tests utilised filled cans, while the other half utilised empty cans. This decision was made because the empty reusable packaging can also be dropped. The cans were dropped both horizontally and vertically. Nevertheless, upon being dropped, the majority of the cans landed on the edge. The results of the drop test can be seen in figures 15 and 16, and in figure 17 a legend can be found.

There was a difference in the height of dent deviation between cans dropped straight and oblique; the cans dropped oblique had larger dents. The distinction between the thick and thin substrates is also evident in the figures. The maximum difference in millimetres between thick and thin substrate dents is 2.2 mm.

Consequently, using a thicker substrate will significantly affect the number of dents on the packaging. The choice between the two may depend on the amount of dents that the brand owner would tolerate. Considering the results, the thicker substrate will be able to last longer than the thin substrate, which is preferable for packaging that can be reused.

Handling

The third test conducted was a handling test, which existed out of scratch tests. The complete scratch test is available in appendix P. A machine capable of leaving linear scratches on a surface will be utilised for this test. It is possible to determine the force at which the coating layer will be pierced using a variety of weights. To distinguish between acceptable and unacceptable weights, the depth of the scratches will also be measured.

Table 5 and 6 depict the results of the PP coating's depth measurements, while table 7,8 and 9 depict the results of the PET coating's depth measurements.

These findings indicate that the PET coating, which has a thickness of 20 Qm, can withstand a maximum force between 10 and 12 N. The PP coating (40 Qm) can withstand up to 16 N of force. Different layer thicknesses may be the cause of this difference; therefore, further investigation is required. However, the type of scratches and the material's behaviour would remain unchanged. PET does not show scratches when subjected to lower forces. While PP shows scratches with any amount of force, but it does not tear. Comparing the two materials, PET is more scratch-resistant than PP, but PET has disadvantages due to the coating layer tearing at the maximum force.

Thin substrate, straight drop

	1x	5x	10x
0.5m	1	1	1
1.0m	2	3	3
1.5m	4	4	7

Thick substrate, straigth drop

	1x	5x	10x
0.5m	1	1	1
1.0m	2	2	2
1.5m	2	3	4

Thin substrate, oblique drop

	1x	5x	10x
0.5m	1	2	3
1.0m	2	5	6
1.5m	3	5	7

Thick substrate, oblique drop

	1x	5x	10x
0.5m	1	2	3
1.0m	3	4	5
1.5m	3	5	7

Figure 15: Results empty cans

Thin substrate, straight drop

	1x	5x	10x
0.5m	1	1	2
1.0m	2	3	5
1.5m	3	5	10

Thick substrate, straigth drop

	1x	5x	10x
0.5m	1	1	2
1.0m	1	2	4
1.5m	2	4	5

Thin substrate, oblique drop

	1x	5x	10x
0.5m	1	3	4
1.0m	3	5	7
1.5m	6	6	8

Thick substrate, oblique drop

	1x	5x	10x
0.5m	1	2	3
1.0m	2	3	5
1.5m	3	4	6

Figure 16: Results filled cans

Legend	Deviation (mm)
1	0
2	0,5
3	1
4	1,5
5	2
6	2,5
7	3
8	3,5
9	4
10	4,5

Figure 17: Legend drop tests

The choice of material depends on the application and the results of other material research. Each material would possess benefits and drawbacks. Which may be crucial in various circumstances and must therefore be considered. PP would tolerate more scratches, but they would be noticeable. While PET is capable of withstanding minor scratches, they will not be immediately obvious until the coating tears.

Table 5: Sheet 1 PP

Force (N)	Total depth scratch (mm)
2	0
4	0,005
6	0,028
8	0,013
10	0,02

Table 6: Sheet 2 PP

Force (N)	Total depth scratch (mm)
8	0,014
10	0,019
12	0,028
14	0,038
16	0,039

Table 7: Sheet 1 PET

Force (N)	Total depth scratch (mm)
2	0
10	0,004
12	0,005
14	0,022
16	0,021

Table 8: Sheet 2 PET

Force (N)	Total depth scratch (mm)
10	0,007
12	0,004
12	0,005
12	0,02

Table 9: Sheet 2 PET

Force (N)	Total depth scratch (mm)
12	0,005
14	0,019
16	0,019

Industrial washing (and drying)

The results of the washing and drying test are presented in this section, the material test plan for the washing and drying test can be found in appendix Q. The water absorption of both PET and PP has been investigated by co-workers [103]. This won't replicate the exact conditions of a washing and drying machine, but it will demonstrate which of the two materials is better suited for that environment. Appendix R contains a summary of the results of their washing absorption tests.

According to the results of the study, PP is better suited for the humid environment of the dishwasher. This is due to the fact that once PET has transitioned into its glass state, it allows water to form within the coating, resulting in discoloration, blistering, and substrate corrosion. PET typically undergoes its glass transition at approximately 75 degrees. However, under humid conditions, this occurs at approximately 60 degrees. After this, the material's rapid increase in water absorption becomes problematic. Once the PET coating reaches approximately 85 degrees, the effects of water absorption become permanent. PP is more hydrophobic than PET and only permits the passage of water when it begins to melt. This occurs at a temperature of approximately 105 degrees; at this point, any damage is irreversible. In the meantime, the substance remains largely unchanged because it does not absorb water.

It must be made clear that this study does not examine what happens to PET and PP after repeated washings. In addition, although the conditions are not identical, they are sufficiently similar to provide the necessary information for this project. During their experiment, they left the water in the can for roughly as long as it takes to wash the packaging (around 1 h). It is not anticipated that heating PP coating to 80 degrees in a humid environment will result in any issues. However, this must be demonstrated through the dishwasher test in future research.

This information must be considered when determining the material to be used for the reusable packaging. As it is undesirable for packaging to exhibit discoloration or corrosion above 80 degrees. Since the PET coating begins to degrade at 60 degrees, even if the damage is reversible, it should not be considered suitable. Unless an alternative cleaning agent that kills bacteria is used to clean the packaging at temperatures below 60 degrees or the use of pressure to clean the packaging with a lower temperature is utilized.

Closures
The final test that was conducted was a closure test. During this test, Protact® cans were repeatedly opened and closed; the complete research can be found in appendix S. The purpose of this test was to determine whether or not the screw thread would be damaged. The evaluation was conducted with packaging supplied by Zaanlandia.

Each can was opened and closed up to 100 times to determine the durability of the Protact® screw thread. The results demonstrated that the coating remained virtually unchanged, indicating that the screw thread is exceptionally resistant to repeated use. On the top of the screw thread edge of the first can, which was opened and closed in the same location each time, minimal damage was observed.

Based on the results of this test, it can be concluded that Protact® with PET coating can be opened and closed multiple times, at least 100 times. To determine the maximum number of opening and closing cycles for PET and PP using multiple cans, additional research is required.

2.4 Conclusion research phase

The first research question addressed is:
How should Protact® packaging that is reusable be introduced to the market?

To provide an answer to how to introduce reusable packaging to the market. Depends on the needs of the ecosystem and the desires of the consumers. To answer this question, interviews and literature reviews were conducted.

Multiple barriers exist for consumers to choose reusable packaging, according to studies of consumer behaviour. These include the price, the quality of the product, the inconvenience of the system, hygienic concerns, ineffective communication, the risk of refills being unavailable, and the consumers' perceptions. In addition to these obstacles, there are numerous benefits for consumers who utilise reusable packaging. These include a decrease in environmental pollution, a decrease in costs, price incentives, and an increase in customization and convenience. Barriers should be removed and consumers should be encouraged to purchase reusable packaging.

Prior to introducing reusable packaging to the market, the ecosystem also faces a number of obstacles, as demonstrated by the literature and interviews. These include hygienic/food safety concerns, the need for changes to the business model (logistics and cleaning), brand image, traceability concerns, and the need to collaborate. Being part of the implementation of a reusable packaging also has advantages for the ecosystem stakeholder. These include increased customer loyalty, modern technology could be incorporated, consumer perception of the brand's sustainability would improve, and packaging waste would be reduced. Each barrier must be considered when designing reusable packaging, and the same is true when selecting a reusable packaging system.

Regarding the packaging's design, no dents or scratches are allowed at this time. Consumers and brand owners are more likely to accept minor scratches in the future as they become accustomed to them. From a sustainability standpoint, a universal design would be preferred, but from a marketing standpoint, each packaging should be unique. Adding advanced technology such as RFID or a barcode to the packaging in order to track it would be advantageous for brand owners. The design of the packaging should provide the consumer with greater convenience than single-use packaging.

There are several options for the reusable packaging system, including refill at home, refill on the go, return from home, and return on the go. In addition, there is the option to exclusively reuse products; consumers can purchase a single bottle and reuse it. The system selected following research is return on the go. This model required the least amount of adjustment from the customer.

Collaboration with a company such as Loop would also reduce the amount of required ecosystem change. Since they would not be responsible for reverse logistics and cleaning. This would increase the probability that they adopt reusable packaging.

The second research question that was answered in this phase is.
Is Protact® suitable for packaging that will be reused?

To answer this question, technology research was conducted. This includes analysis of production techniques, research on legislation, patents, washing systems, and materials.

Utilising a 2P manufacturing technique for the production of reusable packaging would be most advantageous. This is because there are fewer corners and creases through which food can enter. This would increase the likelihood of packaging reuse. As when food remains in its packaging for an extended period of time, it may begin to grow mould and cannot be sold. Additionally, there should be no corners on the packaging that would facilitate such behaviour.

Legislation research has revealed that there is currently lack of specific legislation on reusable packaging. It must be capable of being emptied and refilled without incurring damage [80]. To prevent littering, metal cans with a capacity of less than 3 litres should be bound to a deposit beginning in 2024 [78]. In the coming years, there will be a new regulation regarding packaging waste. Which establishes recycling and reuse objectives. One of these objectives is to reuse 20% of packaging by 2040 [74].

During material research, numerous studies were conducted. Included among these are microscopic research, transportation research, handling research, industrial washing (and drying) research, and closure research. These were conducted to determine whether or not Protact® could be reused. PP would be the optimal coating material for moist environments, as indicated by the findings. It also demonstrates that using a slightly thicker substrate would positively affect the number of visible dent. The scratch resistance of both substances is a minimum of 10N. The combination of these results and the results of the closure tests suggests that the packaging can be opened and closed multiple times without incurring any damage to the coating.

In conclusion, Protact® with double-sided PP coating and a slightly thicker substrate would be suitable for reuse. However, it was not tested how frequently the material can be reused. After the final concept has been designed and a prototype made from the suggested material has been created, this should be tested.

Chapter 3 - List of requirements

The list of requirements can be found in this section. The list of requirements is made up of requirements and wishes that were identified during the research phase. The most crucial requirements will be listed on this page. Appendix T contains the full list of requirements. Including the test methods, additional explanation, sources and dates.

Starting points
- The packaging should be able to be used with dry food contents.
- The packaging must be designed to be reusable.
- The material used for the primary packaging must be Protact®.

Functional requirements
- When the packaging is closed it must not spill the contents.
- The packaging should be able to be used to poor the food contents into a bowl or other dishes.
- The packaging should be able to be stacked on top of each other.

Technical requirements
- The reusable packaging must not cause any (minor) injuries.
- The packaging should be able to be traced.
- The inside of the packaging must not corrode.

Scenario requirements
- The packaging must have temper evidence.
- The user should know how the reuse systems works within 5 minutes of looking at the packaging.
- The packaging should be able to be transported in a supermarket carts without any visual damages.
- The packaging should show the consumers what food is stored inside of it.
- The design of the packaging should be made in a way that dents are not that visible.

Ecosystem & consumer requirements
- The price for the reusable packaging should not be more than 10% above the price of the single-use alternative.
- The reusable packaging should adhere to the brand image.
- At the end of life of the packaging, the packaging should be recyclable.
- The material costs should be as low as possible.
- The business plan should ensure that all stakeholders gain a positive benefit from collaborating for reusable packaging.

Material requirements
- The coating of the material should be intact after 10 reuse cycles.
- After washing with washing detergents the adhesion of the coating of Protact® should not have changed.
- The composition of the material should not change during the heating, using and returning of the packaging.
- The washing system should not go over temperatures of 90 degrees.

Legislation requirements
- By the end of 2024, product responsibility schemes must be established for all packaging.
- The information on the packaging must not mislead consumers.
- The amount of waste of packaging must be decreased. By means of deposit schemes, economic incentives and minimum recycling rates for each packaging type.

Tata Steel requirements
- The packaging should be able to be used by Tata Steel to demonstrate to brand owners what the possibilities are of Protact.
- The packaging should be designed for the food industry.

3.1 Test methods

There are several test methods techniques that can be used. In this section the methods will be explained. The majority of requirements require measurement in order to be met. These involve measuring or verifying compliance with the specification.

User testing is yet another method of testing. These are end-user-centric requirements. Therefore, an interview or online survey must be conducted to fulfil this requirement.

In addition to this test method, another test method requires repetitive setups. Such as the ability to survive a fall from a certain height. This must be tested by performing multiple drops and then determining whether it meets the requirements.

The final type of testing method requires time. Since these requirements require the packaging to be sealed with food for several months. To determine whether life span of the food inside the can is sufficient.

Chapter 4 - Design phase

Using the findings from the research phase and the requirements from the list of requirements, the design phase was started. At the start of the design phase, not all material research, such as the washing and drying test, has been completed. However, it was still possible to proceed because previous research had already demonstrated the effects of washing Protact®. Such as corrosion at the material's open ends. During the design phase, this information will be considered.

The design phase consists of a few sections. It starts with idea generation, which consists of mindmaps and brainstorms. The ideas generated by these techniques will be utilised in the ideation phase, during which sketches will be created. These sketches will be divided into the same aspects that were used in the mindmaps and brainstorming sessions. The morphological overview will combine the most promising sketches. Which will then be used to generate four concepts. The phase ends with a concept choice in which surveys were used and a scoring table. The chosen concept will be elaborated on in the next chapter.

4.1 Idea generation

As previously stated, the design phase will start with the generation of ideas. Which is made up of mindmaps and brainstorms.

Several techniques have been used to generate ideas for reusable packaging. These include mindmaps, brainstorms, and morphological overviews. These will be explained and the results will be displayed in the subsequent section.

4.1.1 Mindmaps

Mindmaps were the first technique used to generate ideas. This was chosen in order to gain a general understanding of the important aspects from the research phase. Mindmaps were useful for this because they are a simple method for gaining structured ideas quickly. The central points of the mindmap were the aspects. After determining this, ideas that came to mind were added to this particular aspect. These concepts would ultimately serve as inspiration for idea sketching.

Mindmaps were also created to help guide the brainstorming sessions. As it was essential to have some general aspects and ideas in mind. In the event that the brainstorm stalled due to a lack of aspects, the aspects used for the mindmaps as well as the generated ideas could assist.

The aspects that were determined to be crucial during the research phase are packaging strength, scratching, transportation, hygiene, convenience, closures, and corrosion edges. Figure 18 shows the mindmap of strength, figure 19 shows the mindmap of scratching and figure 20 shows the mindmap of closures. The remaining mindmaps can be found in appendix U.

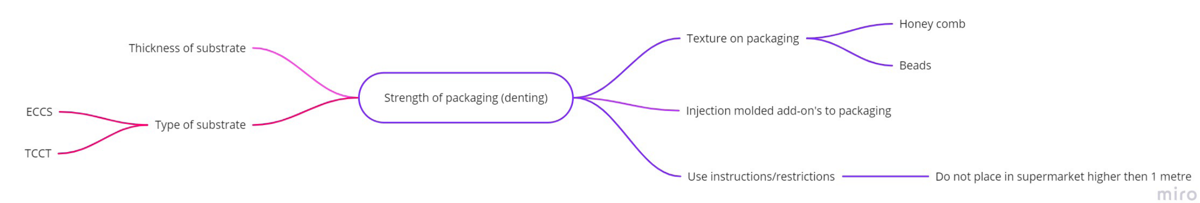


Figure 18: Mindmap strength of packaging

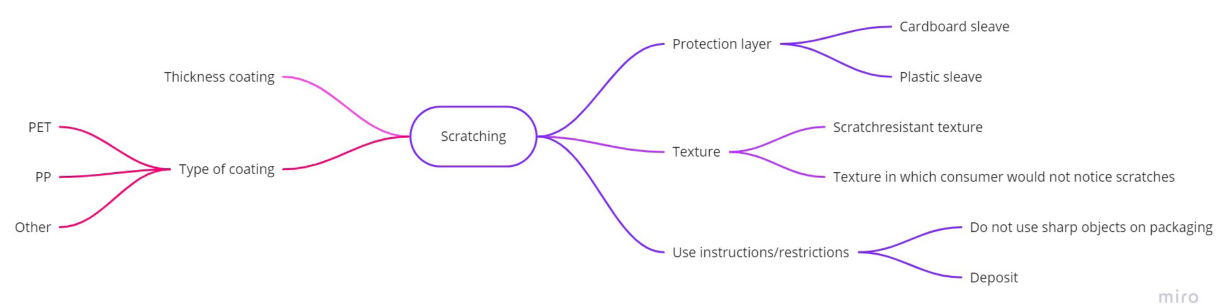


Figure 19: Mindmap scratching

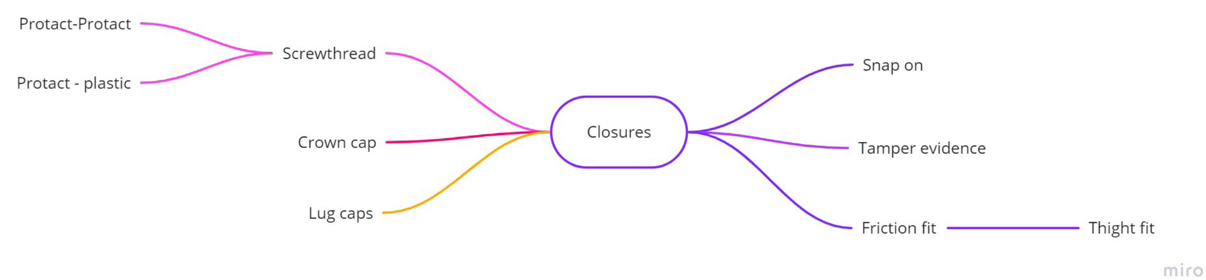


Figure 20: Mindmap closures

4.1.2 Brainstorm

Brainstorming was the second method used to generate ideas. In contrast to mindmaps, this technique involves multiple people. Due to this, it was possible to obtain the perspectives of others on the project. This technique was chosen because a single individual may overlook a crucial aspect, whereas this is unlikely with multiple individuals.

The brainstorming process was repeated twice. One with the marketing team and the other with the R&D team. This was chosen because these teams have diverse perspectives. These individuals have a unique way of thinking, which aids in the development of novel concepts and perspectives.

The brainstorming session began by identifying aspects in silence, allowing participants to determine the frequency with which particular aspects were mentioned. After a couple of minutes (or when inspiration had passed), the aspects were combined. The next phase of the brainstorming session involved generating ideas for these aspects. This occurred partially in silence and partially while speaking. This was chosen because thinking aloud may generate ideas in the minds of others, even if an idea expressed is not useful. The brainstorm plan can be found in appendix V, and the images captured during the brainstorming sessions of the marketing and R&D teams can be found in appendix W. Figure 21 depicts the digitalization and translation of the marketing brainstorm post-its.

The brainstorm wall is divided into two sections. The white background contained information relevant to all stakeholders except the consumer, whereas the purple background contained information relevant to the consumer.

On the marketing team's brainstorm wall, it is evident that they are more concerned with persuading consumers/brand owners/retailers than with material or production. Costs were not previously mentioned as an important factor; however, it should be taken into account.

The R&D team's digitalized and translated post-it notes are displayed in figure 22. They are grouped together in the say way as the marketing team.

The R&D team's brainstorm wall emphasises the packaging's usability and producibility. There is also an emphasis on dosing and pouring the food. These brainstorming walls illustrate the distinction between marketing and research and development; both are quite useful and encourage a different way of thinking about previously determined aspects.

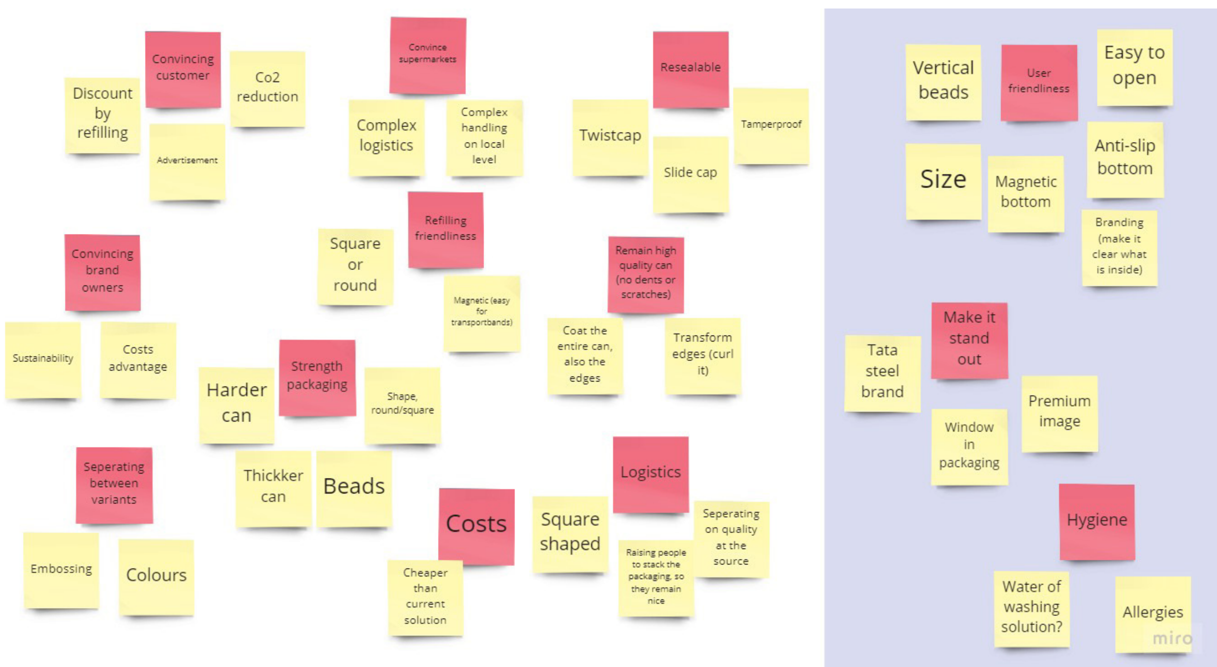


Figure 21: Brainstorm wall marketing

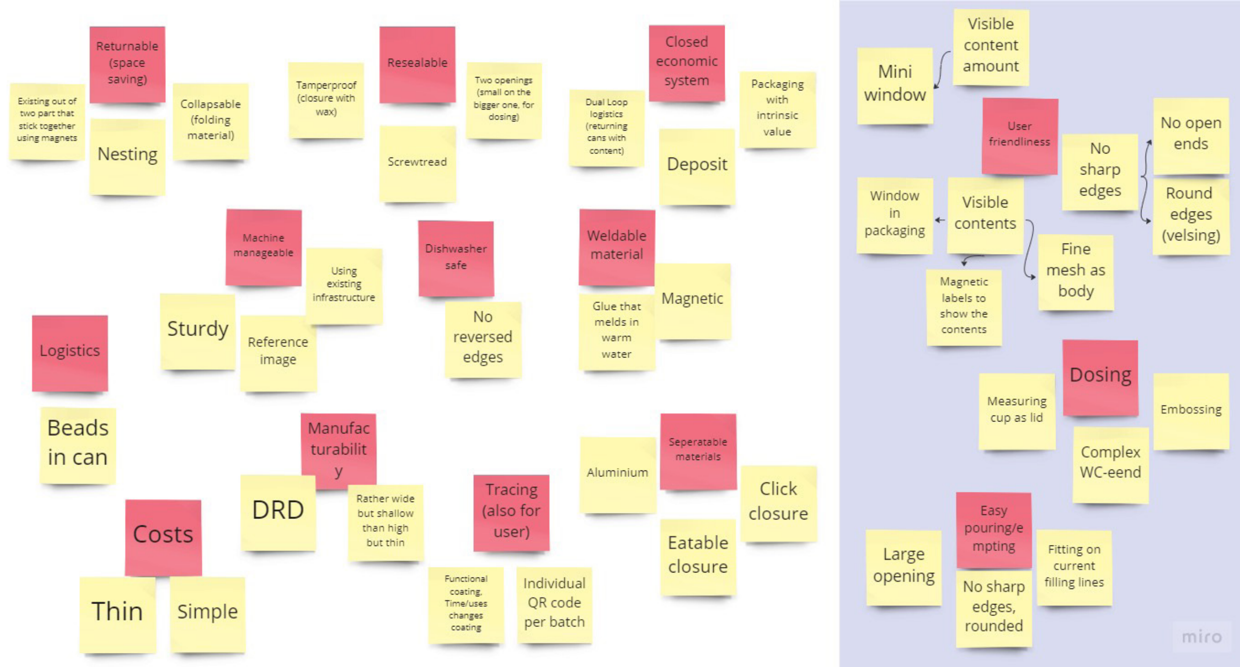


Figure 22: Brainstorm wall R&D

4.2 Idea sketching

Idea sketching is the next step in the design phase. When generating ideas, every aspect generated during research or brainstorming will be considered. These aspects will be placed in a morphological overview, and ideas will be generated for each aspect.

The morphological overview included a number of aspects. The first aspect is strength; the ideas that were generated for this aspect should ensure that the packaging is strengthened in the areas that were weak during the drop tests.

These are the packaging's edges; the sides were mostly intact or there was a small possibility that they would be damaged. In addition to strengthening, it is also possible to camouflage the dents that are created, so they are less noticeable due to packaging or design shapes, for instance. Aspect strength is depicted in Figure 23 in a few different ways.

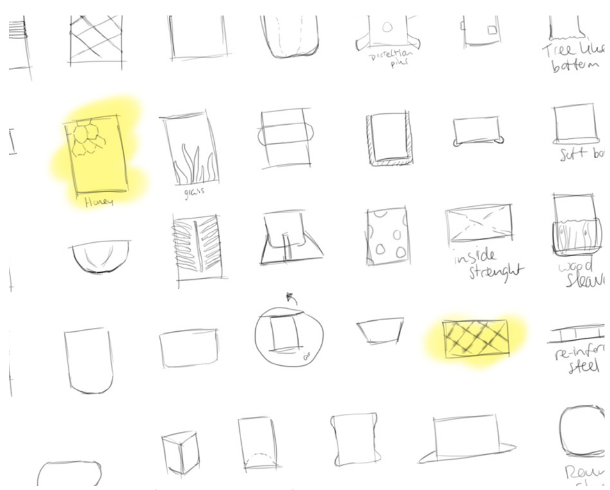


Figure 23: Ideas strength

The second aspect included in the overview is the packaging image. According to the research, it was crucial for the packaging to have a premium appearance. The image should also ensure that the packaging appears clean and sturdy, so that there is no doubt regarding the cleanliness and safety of the packaging. Some concepts for packaging's aspect image can be seen in Figure 24.

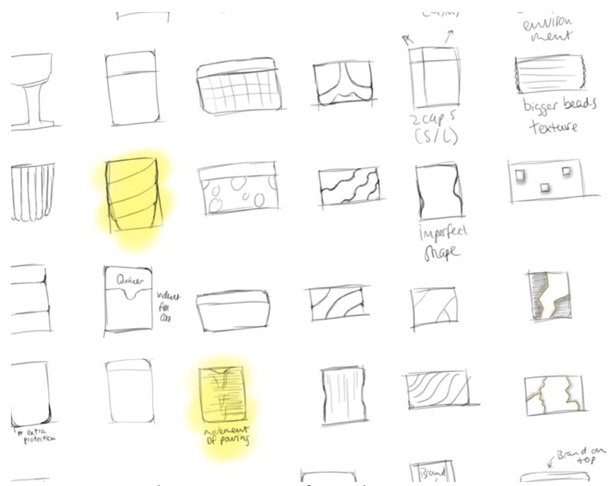


Figure 24: Ideas image of packaging

The third aspect elaborated on is scratching. The ideas generated for this aspect should prevent scratches from occurring on the packaging's coating. As imperfections could cause consumers to disregard the packaging. Ideas that would make the scratches less noticeable were also considered. As it would be possible, for instance, to conceal scratches by altering the packaging design. Figure 25 depicts some of the ideas generated for the aspect scratching.

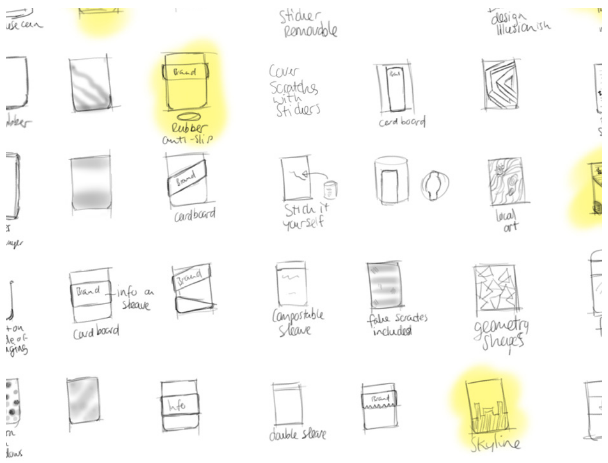


Figure 25: Ideas scratching

The fourth aspect was convenience. Since the packaging is reusable and will be used multiple times, it is possible to increase the consumer's convenience by adding a feature that would not have been possible otherwise, for example due to cost constraints. Therefore, the ideas that were generated for this aspect all increase the convenience of using the packaging. This may serve as an additional incentive for consumers to switch from single-use to reusable packaging. Ideas that were generated for the aspect of convenience can be found in Figure 26.

Figure 26: Ideas convenience

Closures are the sixth aspect that has been added. Different types of closures were created for this aspect. The seventh factor was corrosion edges, which had to be included because this would be a problem when washing the packaging. Different concepts were generated to seal the edges. The aspect tracing was added last. This aspect illustrates the various options for packaging tracing.

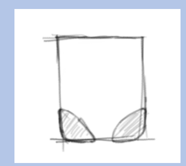
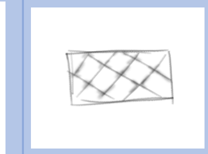
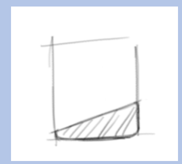
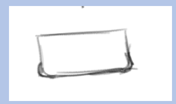
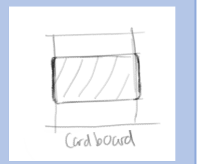
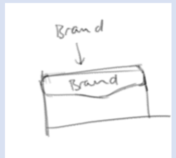
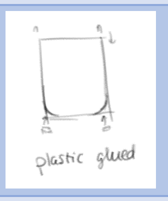
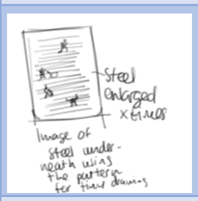
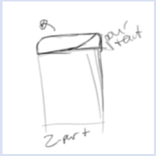
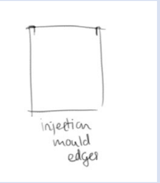
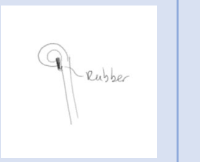
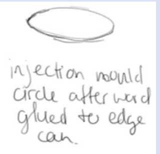
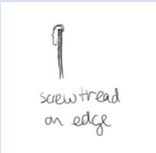
Appendix X contains all of the sketches. The concepts selected for the morphological overview can also be viewed. With the yellow marker, these sketches are highlighted.

In addition to the aspects used to create the sketches, there were additional aspects that were not included but will still be considered. They will be considered in the development of one concept and the selection of a concept, as these are all crucial factors. These factors include price, logistics, hygiene, manufacturability, and persuading the consumer/ brand owner/retailer.

4.3 Morphological overview

Concepts have been developed using the morphological overview. Important aspects will be listed in the column to the left, while the other columns to the right contain one idea per column. The ideas included in this overview are the ideas highlighted in the sketches from the previous section. They were chosen because those ideas are the most intriguing and have the most potential. Table 10 show the morphological overview with sketches.

Table 10: Morphological overview

Reusable packaging	Idea 1	Idea 2	Idea 3	Idea 4	Idea 5
Strength					
Image of the packaging					
Scratching					
Convenience					
Closures					
Corrosion edges					
Tracing	No tracing	RFID	QR-code	Barcode	NFC

4.4 Concept generation

The development of concepts comes next in the design phase. This section utilises the morphological overview from the previous section. There are four concepts created. This section will explain the concepts. Because there were numerous possible combinations, the decision was made to create four distinct concepts, so that all interesting partial solutions can be seen.

Concept 1 - Blue

Concept blue employs magnetic labels on the front and back of the can, as is shown in figure 27. These magnetic labels are constructed so that they cannot be easily removed/fall off. Because labels are used, it is possible for multiple brands to use the same packaging. Without completely losing their brand identity. Consumers would recognise the products more by the label and colour scheme than by the packaging itself. The edges of this concept are protected by a plastic layer. This is injection-moulded and attached afterward. This has been chosen to keep costs as low as possible for this concept. Additionally shielded is the packaging's bottom edge. This was chosen because this is a vulnerable area when the packaging falls to the ground, resulting in fewer scratches and dents. You can tell that the packaging is made of steel because the packaging itself is colourless. This will demonstrate to the consumer that the packaging is durable and more sustainable than the alternative.

Table 11: Morphological overview blue

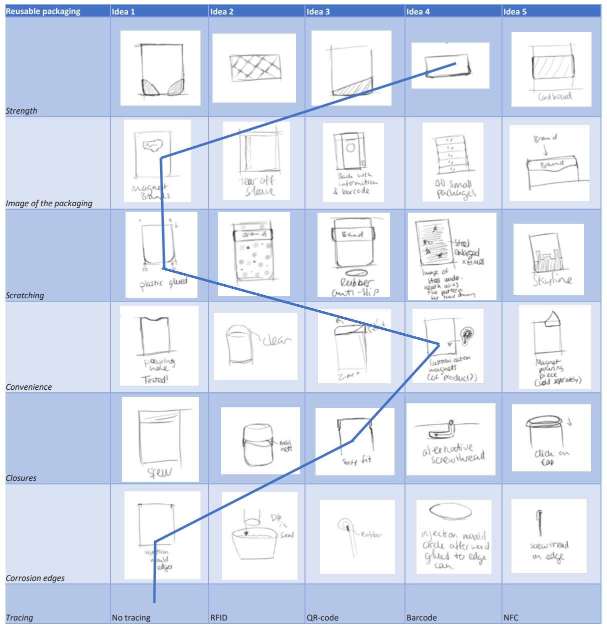


Figure 27: Concept 1 - Blue

Concept 2 - Green

The green concept utilises a customizable lid, allowing the brand owner to differentiate himself by customising the lid's branding. Figure 28 shows concept 2 green. In this case, the lid contains all the necessary information. Several businesses can use the packaging itself. This packaging utilises an easy pour, which functions similarly to a spout but is designed in reverse so that there are no protruding parts, but it still makes pouring the product easier. With this design, the edges are protected by injection moulding plastic directly against them, which also allowed for the placement of an RFID chip at the base. This chip can then be used to monitor the frequency of packaging usage. The design of the can's exterior is inspired by a microscopic image of steel after it has been rolled. Because the lines are not straight, it will be less noticeable when scratches occur; additionally, stick figures have been added to fill in the "scratches." When a new scratch appears, it may appear that stick figure must still go there to fill it, but research must be conducted to confirm this theory.

Table 12: Morphological overview green

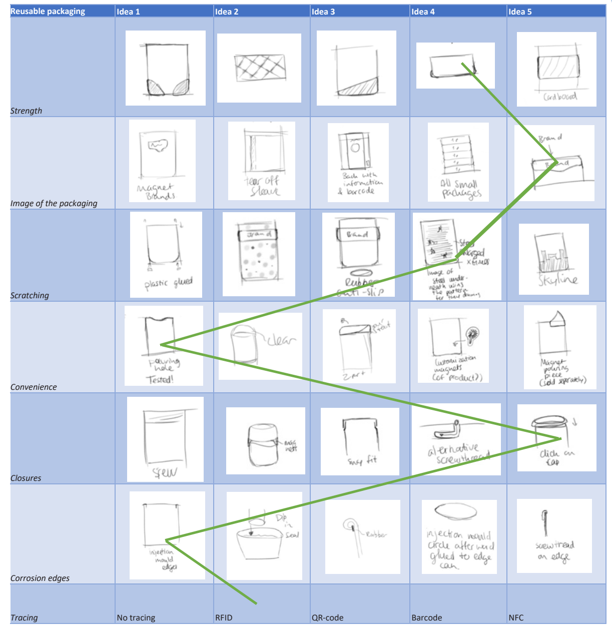


Figure 28: Concept 2 - Green

Concept 3 - Yellow

The yellow concept uses a recyclable and customizable cardboard sleeve. In figure 29 concept 3 can be found. With this concept, the brand owner will adjust the sleeve while the can remains unchanged. Because the sleeve extends over the edge, the packaging's bottom edge is protected from scratches. This packaging's lid is made of transparent plastic so the consumer can see inside. For instance, to determine how much is still there or whether it is still edible. The open edge of this concept is protected by injection moulding a plastic screw thread directly onto the metal, which seals the edge immediately. When the sleeve is removed from the packaging, a QR code is revealed, which is initially used only by the owner of the cans to track how often it has been used, but could also be viewed by the consumer to determine, for instance, how much money they have saved by using reusable packaging.

Table 13: Morphological overview yellow

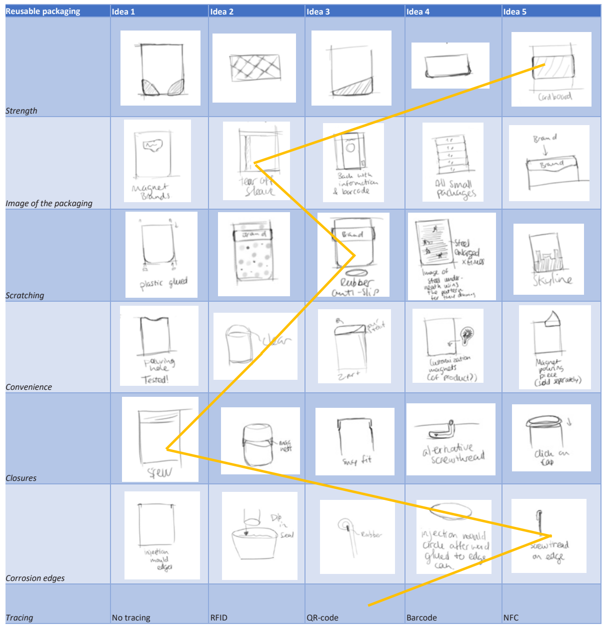


Figure 29: Concept 3 - Yellow

Concept 4 - Red

Concept red is the only concept that makes use of square packaging, as seen in figure 30. This was chosen to maximise the use of reusable packaging's surface area. This concept also employs a sleeve, but there is a distinction between it and the preceding concept. In this concept, the customer removes this sleeve in order to access the content. Consequently, the packaging is better protected during processing in factories and supermarkets as well as during transport. Once the item is in the consumer's possession, he or she may keep the sleeve for the return. In the interim, the consumer can use magnets that can be personalised to display the food contained in the can. So that the consumer can see what is in the cabinet. In this design, the open edges are protected by folding them over and inserting a piece of plastic in between, preventing water from reaching the edge. This can's design was intended to make scratches and dents the least noticeable because there is no effect colour and no tight stripes, but as with the other design, this will need to be tested further.

Table 14: Morphological overview red

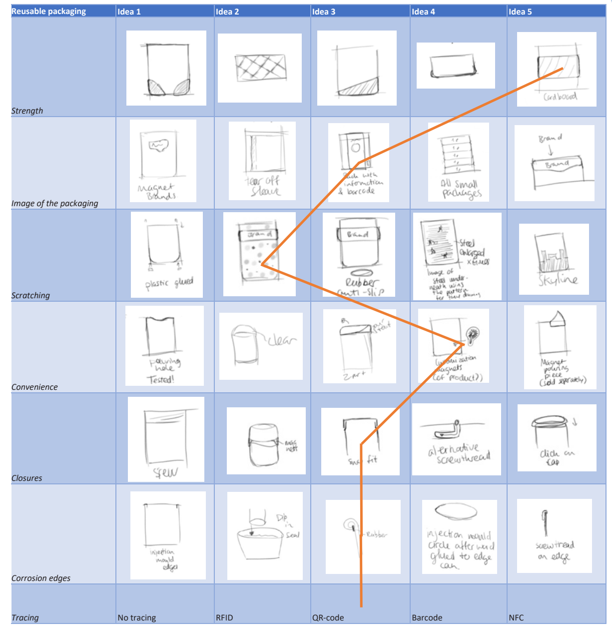


Figure 30: Concept 4 - Red

4.5 Concept choice

The concept choice consists of two parts. The first section employs a scoring table, while the second section utilises a survey-based decision tool, as detailed in Appendix Y. During concept selection, it was decided to create the scoring table before reviewing the survey results so that the scoring table's results would not be influenced by the survey's findings.

4.5.1 Scoring table

The scoring table demonstrates that the results of the four concepts are comparable. However, there are substantial differences. Concept 1 has 84 points, Concept 2 has 95 points, Concept 3 has 105 points, and Concept 4 has 90 points. Concept 3 has the most points because using a sleeve would prevent the material from showing any scratches or dents, allowing the packaging to be used for a longer period of time and the material coating to degrade less quickly. In addition to this, the transparent cap provides an additional functionality to the metal packaging that would not otherwise be possible.

The packaging's ability to be manufactured is a strength of concept 1. This is the simplest design that can be manufactured. Comparable to concept 3, concept 2 is in second place. The scratch resistance of the concepts differs. Concept 2 is more convenient than Concept 1 due to its easy pour hole and snap fit. Concept 4 comes in third, but its score is lower due to limitations in manufacturability, as this packaging cannot be produced using 2P production techniques.

4.5.2 Concept choice survey

81 Tata Steel employees have completed the survey. Due to sensitive information, the survey was restricted to Tata Steel only. The results of the survey indicate that the concepts score similarly, but there are some distinctions. Concept 1 receives a rating of 3.22, Concept 2 receives a rating of 3.38, Concept 3 receives a rating of 3.48, and Concept 4 receives a rating of 3.46. This also demonstrates that concepts 3 and 4 are the most popular.

The next question asked, "Which concept appeals to them the least?" Concept 1 (30%) and concept 4 (30%) received the most responses. Another question asked which concept would be the most marketable, and concept 3 was clearly the winner with 42% of the votes. Concept 1 has the lowest sellability (32%), followed by concept 4 with 25%.

The final few questions can be grouped together. This question asked which concept you would elaborate on and whether any additional aspects should be included. The concept that was chosen the most was concept 2 (28%), but concept 4 (27%) and concept 3 (26%) are also very close. Transparent cap and easy pour were cited as the features that should be added most frequently.

Interestingly, it can be observed that the survey results align with the scoring table results. With the exception of concept 4, this one scores lower than it did in the survey.

4.5.3 Final concept choice

The decision has been made to base the final concept on concept 3 - yellow. Due to the results of the scoring table and the survey. The concept satisfies virtually all requirements, including the most important ones, such as scratch resistance and convenience. However, to increase the convenience even further, the easy pour feature will be added to this design, and because of this, the screw thread will be eliminated and replaced with a snap fit. In addition to making it easier to remove than a screw thread, this also reduces the amount of material required for injection moulding the edges. The revised concept 3 can be found in figure 31. The sleeve has also been modified slightly, as feedback from the survey indicated that consumers desire to remove the sleeve. Therefore, the sleeve will be designed so that a machine can remove it, allowing the consumer to keep it on while returning, which would also solve Loop's sticker problem.

Figure 31: Final concept

Chapter 5 - Detailling phase

During this phase, the final 3D model will be created and refined. First, the model will be improved based on technical feasibility, and then it will be used to create a business plan and to perform an impact assessment on the environment.

5.1 Technical feasibility

This section will elaborate on the technical feasibility of the final concept that was chosen in the previous chapter. There are specific areas that require additional research to ensure it can be manufactured. This section will discuss the dimensions of the packaging, the easy pour, the attachment of the sleeve, nesting, injection moulding to the edge, tamper-evidence, and the QR code.

5.1.1 Dimensions of the packaging

As the reusable packaging is intended to be used for multiple dry products, the packaging size was determined based on the volume of various breakfast cereals, taking into account the varying volumes of each type. Kellogg's Smacks had the highest volume-to-weight ratio of the two types of Quaker cereal used to determine the packaging size. Appendix Z provides information on the volume measurement setup, which yielded an average volume of approximately 1270 cm3 for the reusable packaging.

When determining the size of the packaging, ergonomics were also considered, specifically the need for consumers to comfortably hold the packaging with one hand while holding a bowl with the other. In order to accomplish this, research was conducted using 3D model version 3, which resulted in a maximum diameter of 78mm for female hands and 89mm for male hands, as seen in appendix Z. Even though it is possible to deviate slightly from these dimensions, comfort is essential, so deviations should not be excessive.

The location of the packaging's storage is also an important consideration. Specifically, the size of kitchen cabinets and grocery store shelves. The average height of the shelves is 30 cm [1], but they are adjustable. The minimum kitchen cabinet depth is 19 cm [2,3].

5.1.2 Easy pour

A short research was performed to determine whether implementing an easy pour would improve the pouring of food products. Appendix AA contains a the full research results. For the research, 65% scaled-down versions of four types of easy-pour 3D models were created, the design was based on version 3 of the 3D model. Figure 32 depicts these four types from left to right.

The research demonstrated that using an indentation as an easy pour can indeed reduce the width of the dry food pour, making it easier to pour into smaller containers without spilling and allowing more precise portioning. Version 3, which had straighter edges than versions 1 and 4, had the smallest pouring width and provided the most guidance of the four tested easy-pour designs. Therefore, version 3 of easy pour will be used in the final design.

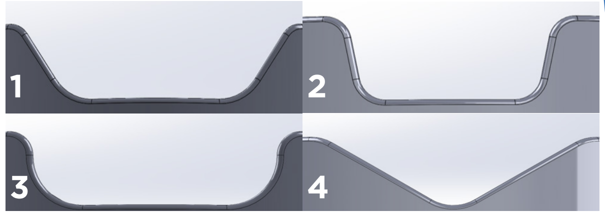


Figure 32: Easy pour 1,2,3 and 4

5.1.3 Sleeve attachment

A type of attachment is required to ensure that the sleeve remains in place once it has been wrapped around the packaging. Various types of adhesives have been investigated for this purpose. Appendix AB contains the complete research.

PVA and EVA are types of glue that may be utilised. EVA is a strong, water-soluble adhesive [4,5]. However, it does not specify the time required for dissolution. The other type of adhesive PVA is weaker and also water-soluble[6]. The dissolution time for PVA glue is around 10 minutes [7]. It may still be necessary to remove the glue residue manually from the packaging. Since this is undesirable, another solution that does not involve glue has been developed. Another way to prevent the sleeve from slipping off is to physically prevent it from falling. This can be accomplished by adding embossing to the exterior of the packaging and creating holes in the sleeve so that the embossing supports the sleeve. As depicted in figure 33.

Figure 33: Embossing on outside packaging

5.1.4 Nesting

In order for the reusable packaging to be nested, it is necessary to investigate how the packaging can be easily disassembled after it has been nested. Existing packaging was analysed for this purpose, and the results can be found in appendix AC along with a detailed explanation of the nesting versions it went through.

First, an indentation has been added to the bottom of the packaging to ensure that there is still air in the bottom when the packaging's are nested. However, this was not sufficient to prevent them from staying together. A lower rim has been created because the final design's rim was not low enough to prevent packaging from staying together (as can be seen in the appendix). Since this did not look good and the cap needed to be larger, a different solution was required.

The embossing created for the sleeve will be used to prevent the packaging from sliding too far into each other, as the embossing on the packaging will prevent this. Figure 34 and 35 illustrate the nested packaging.

Figure 34: Nested 3D model v.4

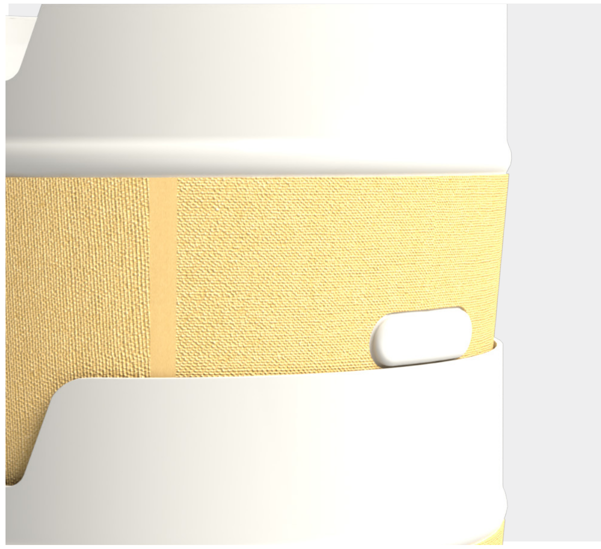


Figure 35: Detail nesting

5.1.5 Injection moulding to edge

The edge of the packaging will be injection moulded due to the necessity of sealing the edge of Protact®, which would otherwise begin to corrode after cleaning. If the injection mould is too thick, more plastic will be burned off when the material is eventually recycled. In addition, the law stipulates that a small percentage of single-use packaging may be composed of a different material. For the reusable packaging, it is also preferable that the packaging be composed primarily of a single material, mono-material. Additionally, the injection-moulded edge will be utilised to ensure a tight seal. To achieve this, the upper edge of the injection mould has been made slightly thinner, while the lower edge has been made slightly thicker, so that when the cap is placed on there is a good seal. As depicted in figure 36.

Figure 36: Snap fit detail

5.1.6 Tamperproof

To demonstrate to consumers that the packaging has not been opened and the food has not been tampered with, tamper evidence is required. Appendix AD explains the various types of tamper-proof evidence [8]. Decorative labels have been selected for this application as the tamper-proof evidence.

The selected decorative label is created from paper. The label will tear when the package is attempted to be opened [9]. As opposed to having to cut the tamper-evidence with a knife [10], the consumer does not need to perform any additional steps prior to opening the packaging. Figure 37 depicts an example of a tamper-proof evidence sticker.

Figure 37: Tamper evidence sticker

5.1.7 QR code

Using a sticker, the QR code will be placed on the packaging. Due to the sleeve covering the QR code, the sticker will not be visible to consumers who utilise the packaging. It is essential that the QR code sticker is durable and reusable. The sticker must be able to withstand multiple washings cycles without falling off.

The cleaning company and the owner of the brand will use the QR code to trace the packaging. This would ensure that the packaging can be utilised for at least 10 cycles. This information could be used in the future to prevent product failure. Figure 38 shows the packaging with QR on the packaging.

Figure 38: QR on packaging

5.2 Material choice

This section will present the rationale for the chosen material based on the results of the material research conducted. The material type, Protact®, was selected at the outset of the project, but there are several possible Protact® coatings. The research focused on PET and PP because Tata Steel currently produces these two types of laminates, with PET being produced more frequently. Other types of plastics were also investigated, but they were deemed too expensive and unable to offer significant production advantages.

The material research revealed several advantages and disadvantages of both PET and PP, which are summarised in Tables 15 and 16.

Table 15: Advantages and disadvantages PET

PET	
Advantages	**Disadvantages**
High melting tempera-ture	Water sensitive above glass transition
Highly scratch resistant	Above glass transition edges might release and expose substrate
Transparent	When scratching force is too high the coating tears

Table 16: Advantages and disadvantages PP

PET	
Advantages	**Disadvantages**
High melting tempera-ture	Water sensitive above glass transition
Highly scratch resistant	Above glass transition edges might release and expose substrate
Transparent	When scratching force is too high the coating tears

PET is a harder substance than PP. This difference in material behaviour affects scratch resistance, an important consideration for packaging that can be reused. However, the selected concept for the packaging design, as depicted in the 3D model and concept sketches, includes a sleeve, which eliminates the majority of the disadvantages of PP because the scratching will occur on the sleeve and not the material. This also applies to printing. Moreover, cleaning the reusable packaging is of the utmost importance, so PP was chosen over PET, which is known to undergo material state changes when exposed to water and heat. Due to the milky nature of PP's transparent coating, PP cannot be coated with a transparent layer. Therefore, the chosen colour for the can would be white.

However, PET could be used without a sleeve if the company responsible for cleaning the material used a lower temperature and gentler cleaning agents. This is only possible if a single brand uses the packaging, as the coating printing would need to be permanent. Which is not preferred.

Last but not least, it would be preferable if the substrate thickness were a bit greater. According to research, there are substantial differences depending on the thickness of the substrate. Nevertheless, it must be demonstrated through a sustainability calculation that increasing thickness reduces environmental emissions. When the impact is minimal, it is acceptable to opt for a thinner substrate. The chosen thickness for the material is 0.25 millimetres. This is thicker than a standard can, but this is required in order to produce a larger can.

Cap

PET has been selected as the optimal material for the cap due to its transparency and resistance to repeated cleaning cycles. Since there is no direct steel contact, there is no risk of corrosion. Additionally, PET is a cost-effective material that can be poured thicker to achieve the required application-specific strength.

Sleeve

The chosen material for the sleeve is white-sided folding box board (FBB) of type GC1 [11]. Which is a material that exist out of several layer. The inner layers are made of pulp, while the outer layers are printable liners. It is preferable when the pulp is made from recycled materials. The sleeve's grammage is determined to be 200 g/m2. This is on the low end of the range for carton board grammage [12]. This was chosen because the FBB does not require strength to hold the packaging together; it is employed to prevent surface damage and for marketing purposes.

5.3 Production technique choice

This section describes the production technique chosen for the reusable packaging and outlines the required production steps. As mentioned in section 2.3.1, there are a variety of production techniques to consider. The draw redraw (DRD) technique, combined with an ironing step, was ultimately selected due to its ability to produce 2P cans with fewer ridges, thereby decreasing the likelihood of food remaining in creases. The calculations used to determine the number of packaging steps are included in Appendix AE.

Figure 39 depicts the stages of manufacturing the main can. This figure depicts three drawing steps, with the final step being a combination of drawing and ironing. This decision was made because the upper edge of the material is typically thicker during the drawing process. Ironing this part reduces the required amount of material while maintaining the required dimensions.

Once the correct height and diameter have been determined, the can is tapered in a separate process. The next step is stamping, which creates the embossed pattern on the main can. Following this step, any excess material and the easy pour are cut. These procedures conclude the manufacturing of the main can. Before injection moulding the cans to the edge, they must be cleaned. Since PP is used as a coating, the stamps used in the drawing process must be waxed to prevent the coating from tearing. This wax must be removed before proceeding. The main can is ready for assembly with the sleeve and cap once the material has been moulded to the edge.

SolidWorks was used to create the injection moulds for the cap and the edge to demonstrate their appearance. Appendix AF describes the creation of the moulds, as well as the simulation demonstrating that they can be injection moulded.

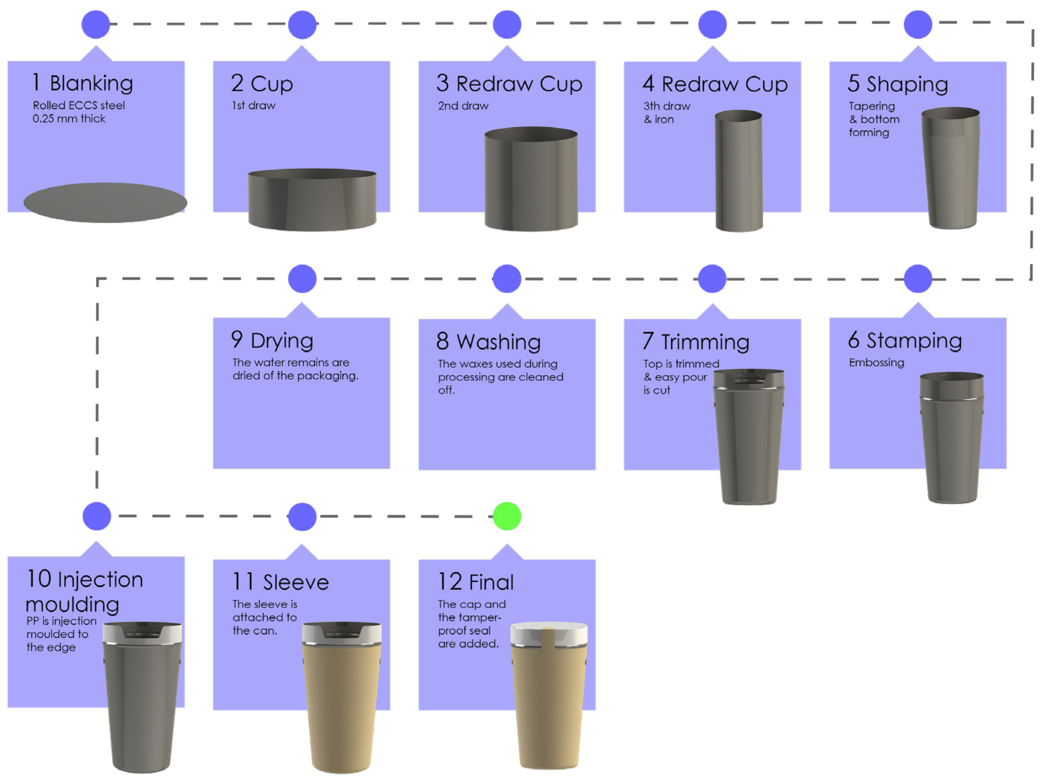


Figure 39: Production steps of main can

The cap mould was the first to be created. The sides of the cap were already designed with a small draft, but this was insufficient to enable the part to be removed from the mould. The angle measured 0.1 degrees when a minimum of 0.25 degrees was required [13]. As a result, the cap and injection mould to the edge were slightly modified. The cap's mould is a simple two-piece design with a single injection point, which was sufficient to fill the entire mould. The intersection of the mould is depicted in Figure 40, while the exploded view can be found in the appendix. The figure shows the two parts of the injection mould, the brown part is the top injection mould and the grey part is the bottom injection mould. The white section is the cap.

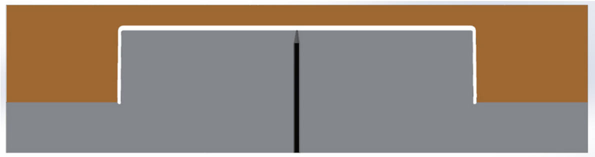


Figure 40: Intersection mould design cap

Before creating the injection mould for the edge, it was necessary to modify the edge's design. An angle in the design would have required more expensive printing material, so the can's edge design was rounded, see appendix. After this modification, there should be no difficulty with edge filling. Figure 41 depicts the intersection of the edge's mould design.

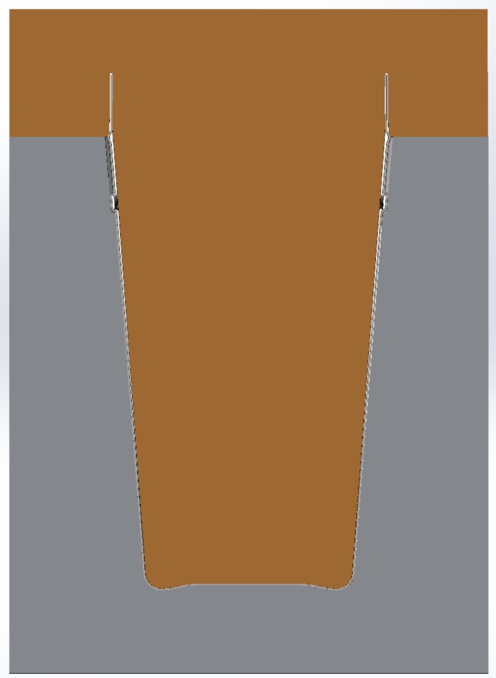


Figure 41: Intersection mould design edge

5.4 Changes

The final 3D model will be displayed in this section. This model will also be compared to the previous version (v.3), and any modifications will be described. The changes from model v.1 to v.4 can be found in appendix AG. Figure 42 depicts models v.3 and v.4 with the modifications highlighted.

Figure 42: Model v.3 and model v.4

1.
The first change that was made was the smoothing of the injection moulded edge. This modification enables injection moulding of the edge, as explained in the previous section.

2.
The second modification was the addition of side embossing. To eliminate the need for glue in the attachment of the sleeve and to facilitate nesting.

3.
The third modification involved increasing the height of the packaging. It was necessary to increase the height because the next modification would require a reduction in the diameter of the packaging's base. To maintain the same volume level.

4.
The fourth modification is a reduction in the diameter of the model's base. In order to improve the packaging's ergonomics. So that people with small hands can also hold the packaging with a single hand.

5.
The fifth modification is the coating's colour. This has been changed to white because a transparent PP coating could make the coating appear milky, which is undesirable.

5.5 Final label design

The label design is the final aspect that needs to be elaborated upon. As stated in the final concept, the reusable packaging is intended for use with multiple products by simply exchanging the label. Due to the harsh conditions that occur with wet food products, such as sterilisation and pasteurisation, the decision was made to only focus on dry food products. In order to account for all dry foods, a supermarket exploration was conducted, which can be found in appendix AH. This investigation led to the selection of breakfast cereal. Nevertheless, pasta, rice, sugar, and cookies could also be chosen.

Breakfast cereal was selected because cereals are transported in cardboard boxes containing plastic bags. Due to the inherent weakness of this food, the cereal must be transported with air, resulting in packaging that is only half full. In addition to adding air for transportation, this is caused by the collapse of cereal after packaging. When food products are initially poured into a bag, their volume is increased. However, after transportation (vibrations), the food products may collapse into one another, resulting in a volume reduction. Which results in the bag being half-empty after transportation. When replacing the packaging material with steel, there is no longer a need for additional air because steel is strong and the product inside will not be damaged by external pressure. Thus, transporting breakfast cereal in a steel packaging will result in being able transport more cereal with less volume. Aside from this breakfast cereal barriers, PP-coated steel packaging presented no other problems for the food (see appendix AI)
.

Breakfast cereal is still too broad a category to create a label. For this reason, various breakfast cereal brands were analysed; the largest cereal brands are listed in appendix AJ.

In addition, the history was examined in appendix AK, which revealed that the breakfast cereals were created by the Quaker Cruesli Company. Due to this, this company was chosen, but it should be noted that the other brand can still be used with the same packaging. This company was chosen to illustrate how the label would appear when combined with the packaging. When analysing the variety of products sold by the Quaker Oats Company, there is still a great deal of variety. In light of this, one specific product will be chosen; the brand's portfolio can be found in appendix AL. Quaker Cruesli Luchtig was chosen as the product for the label and for the other comparisons (in the next sections). As this product is available in the Netherlands, it is possible to purchase its packaging and conduct additional research on it.

With the selected product, a label design was created. The reasoning behind the design of the label can be found in appendix AM. This is a collage of some of the products used as inspiration for the label, as well as a graphical exploration of the Quaker Cruesli Luchtig packaging. Figure 43 depicts the label's layout, including the cutting and folding lines. The cutting lines are coloured red, while the folding lines are coloured black and are dashed.

This layout was used to create the final Quaker Cruesli Luchtig label design. The layout is depicted in figure 44. This design can serve as a source of inspiration for future designs. Important is the fact that images must be slightly skewed to appear straight when folded. Brands can also add product images to the packaging in order to brighten up the label. The blue warning label and blue ribbon must be added to all labels. This was added to ensure that consumers can identify the reusable packaging and return it with the sleeve and cap.

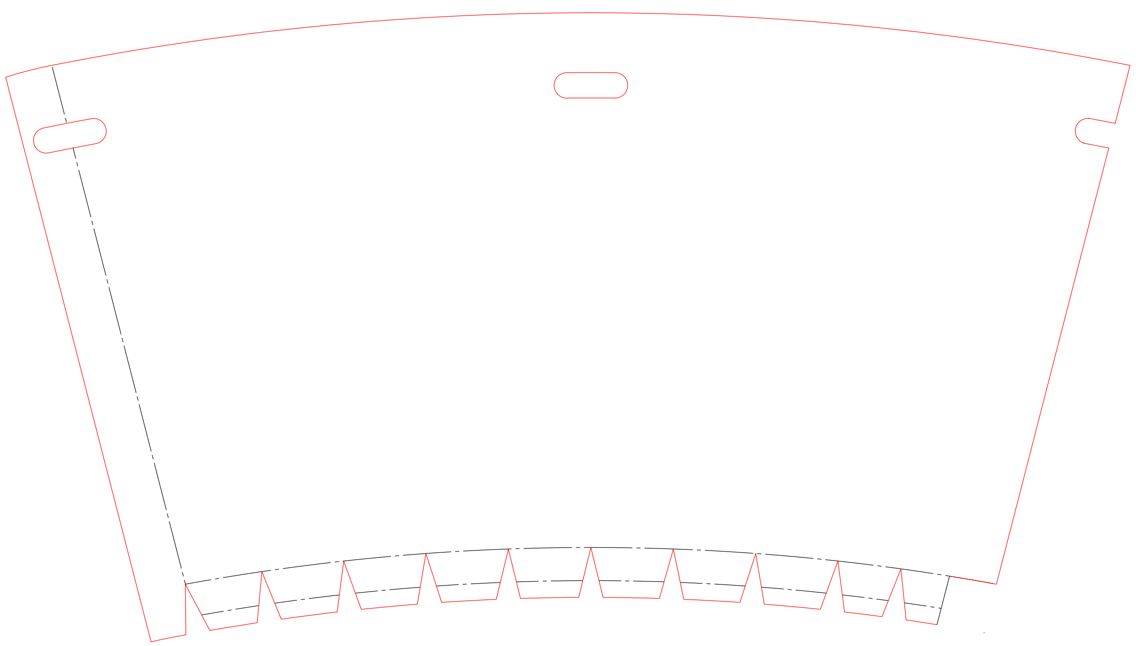


Figure 43: Layout label

Figure 44: FInal label design for Quaker Cruesli luchtig

5.6 Final bill of material

The final bill of materials will be highlighted in this section. This includes a cost price calculation. Appendix AO contains the complete cost-price calculation. The cost price is comprised of the cost of the material, tool, machine, post-processing, and assembly..

Table 17 contains the component list. The weight determined in appendix AN is also shown in this table.

These materials and weights were used to determine the final packaging cost. The total estimated cost of the reusable packaging is 0.90 euro. This includes the cost of the sleeve that will be required each time, which is 0.14 euro each time. The primary can, the DRD steps, and the moulds required to create the stamps are the main contributors to the cost price. The estimated investment costs are approximately 260.000 euros. This includes all of the moulds required for the DRD steps as well as the injection moulds.

Table 17: Parts list

Part nmb.	Name	Material	Weight
1	Main can	Protact® PP	137,2 gram
2	Sleeve	Folding box board (FBB)	11,2 gram
3	Cap	PET	29,7 gram

5.7 Sustainability calculation

This section contains the sustainability calculations. They were conducted to determine whether implementing reusable packaging would be more environmentally friendly than single-use packaging. In order to accomplish this, a life cycle assessment (LCA) was conducted. This consists of a goal definition, functional unit, inventory analysis, models, and environmental impact results.

5.7.1 Goal definition

The first step in conducting a life cycle assessment is defining the goal, which includes determining the research purpose and scope. This method establishes a clear direction for the analysis, ensuring that the results are applicable and useful to stakeholders. By defining the objective and scope, it is possible to make informed choices regarding the data collection and analysis techniques to employ. In addition to the objective and scope, the goal definition includes the functional unit.

Application

The application of a life cycle assessment (LCA) is determined by its purpose and intended audience. In this instance, the objective of the LCA report is to assess the environmental impact of reusable versus single-use packaging and enable the reader to make an environmentally responsible choice between the two.

Subject & depth of study

For future research to be able to replicate this study, it is essential to precisely define the products that will be compared. In this study, two products, single-use packaging and reusable packaging, will be compared. Cereal packaging is the product type that will be compared in this research. Quaker Cruesli Luchtig single-use packaging containing 375 g of cereal will be compared with the reusable packaging created in this report. The packaging can be found in figure 45.

Figure 45: Single-use packaging Quaker Cruesli Luchtig

The reusable packaging contains 450 g and is made from Protact with a PP coating. The cap of the reusable packaging will be made from PET and is transparent. Figure 46 illustrates the recyclable packaging.

Figure 46: Reusable packaging with Quaker Cruesli Luchtig label

This assessment will evaluate all packaging components throughout their entire lifecycle. For single-use packaging, both the outer cardboard layer and the inner plastic bag will be evaluated, whereas for reusable packaging, the can, sleeve, and cap will be considered. External factors, such as truck storage, will not be considered in the assessment. The packaging's contents, in this case the cereal, will not be included in the environmental assessment because both products produce the same emissions. The filling portion of the packaging is also left out because it is assumed that they are identical and therefore do not influence the results.

Another objective of the LCA is to identify opportunities to improve the sustainability of the packaging model. In order to determine the environmental impact of using a plastic clear cap as opposed to a metal cap.

The focus of this analysis will be on Europe, as the reusable packaging is intended for the European market. Consequently, the findings of this study will only be applicable in Europe. The report's temporal validity has been set to five years, which is believed to be sufficient time for any changes that could affect the results to have minimal effect. Since the analysis was performed in 2023, it is valid until 2028. However, future research may indicate that the validity of the study's findings extends for a longer period of time.

Functional unit

The functional unit is used to compare the two products. The packaging will be compared according to the amount of food it can hold and the shelf life of the content. Since the reusable packaging will be filled multiple times, it will be able to hold a greater quantity of product than the single-use packaging. A reasonable and logical quantity of circa 400 grams has been chosen for the specification, as this is in between 375 g and 450 g. It has also been taken into account that the shelf life of the single-use packaging in the retail packaging is considered to be shorter than that of the steel packaging.

The functional unit determined is:

To pack circa 400 gram of dry food in a retail packaging with a shelf life of 12 months for a total consumption of 10.000 gram.

The functional unit will be used to determine the amount of life cycles required to perform the task described in the functional unit. The content of the single-use packaging is 375 g, and the shelf life of the unopened retail packaging is approximately nine months [14]. Aside from this, it is assumed that the food in the packaging becomes stale after being opened for too long; consequently, 95% of the contents of the single-use packaging have been estimated to be consumed. The reusable packaging, on the other hand, has a weight of 450 g and a shelf life of at least one year when unopened, as it is primarily packaged in steel with excellent barriers. Because of this, it is also anticipated that there will be no food waste due to stale cereal. The reusable packaging should be capable of being reused at least 10 times. Keeping this information in mind, the functional unit requires the following amount of life cycles.

Single-use packaging: 42 life cycle
Reusable packaging: 2,2 life cycle

5.7.2 Inventory

Appendix AP contains the inventory analysis. In the inventory analysis, you can find the process and assembly trees for single-use and reusable packaging. This appendix also contains details about the recycling rates utilised during the modelling phase.

Models

Gabi was used to conduct the LCA analysis. It is possible to model the LCA by life cycle stage. The generic life cycle consists of three stages;

Production - use - disposal

These are identical for the two products being compared. During production, every component of the packaging is taken into account.

When modelling the reusable packaging, it was necessary to consider the sleeve separately. As the sleeve is intended for single use and not reuse. Figure 47 illustrates the model of the reusable packaging per life cycle stage.

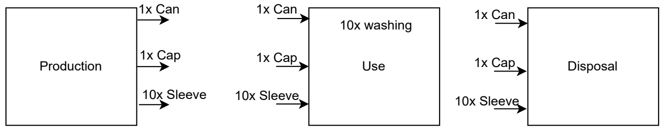


Figure 47: Model reusable packaging per life cycle stage

This model demonstrates that 10 sleeves are required for a 10-times reuse. In addition, the outputs from the use phase, particularly the washing section, are multiplied by 10. As the packaging must also be washed ten times before it can be reused. Any justification for the model is elaborated upon in appendix AP.

5.7.3 Results environmental impact

In this section, the results of the environmental impact will be presented. The dashboard used to compare results with is the CML dashboard, as Tata Steel uses the same dashboard. Using the CML dashboard, appendix AP displays the complete results alongside an explanation for each effect.

Two scenarios were examined during the assessment. One scenario involved a comparison of single-use versus reusable packaging design. Another objective was to compare the reusable packaging with a Protact cap instead of a plastic one. The first scenario also includes a break-even point analysis, as it is necessary to determine at what number of cycles reusable packaging becomes more sustainable. As this demonstrates the viability of the packaging design. Figure 48 shows the results expressed in terms of the 100-year global warming potential (GWP).

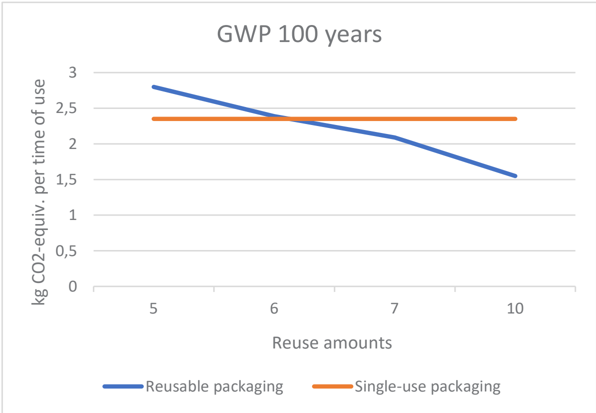


Figure 48: GWP 100 years comparison reusable vs single-use packaging

The graph indicates that seven reuses are required at minimum. At this point, the majority of the CML dashboard's effects are positive for the reusable packaging. The only effect not improved after seven reuses is abiotic depletion elements (ADP), which is better after ten reuses. ADP is the global raw material reduction.

Figure 49 illustrates the outcomes of comparing the version of the reusable packaging with a Protact cap to the plastic cap. This scenario compared ten reuse cycles, as this is the required minimum.

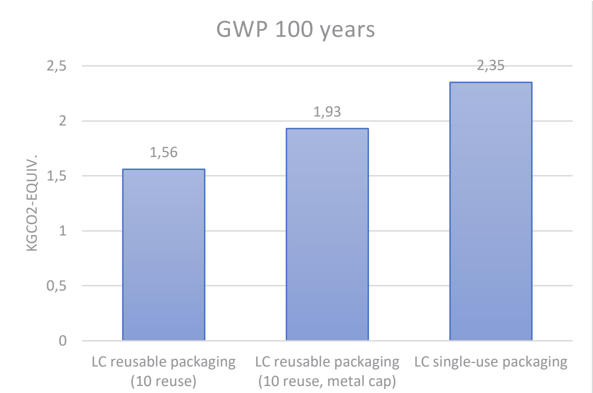


Figure 49: GWP 100 years comparison reusable (metal and plastic cap) vs single-use packaging

These results indicate that using a plastic cap would be more eco-friendly. When the advantages of using a Protact cap are greater, it may be decided to use this cap. Such as improved barriers and a longer lifespan. Since the emissions are still lower compared to the single-use packaging.

5.8 Conclusion design & detailing phase

In this section the conclusions from the design and detailing phase can be found. This conclusion answers the third and fourth research question.

The third research question answered during these phases is.

How would you recommend designing a reusable packaging made from Protact?

To address this question, a concept was developed and refined. The final concept is based on the research conducted during the research phase. The selected concept uses a transparent cap. This ensures that the consumer can see what is inside the packaging and how much is left without having to open the packaging. This would be especially useful when storing the packaging in a drawer. Easy pour is another feature that was added to increase convenience. This ensures that pouring becomes easier and that spills occur less frequently.

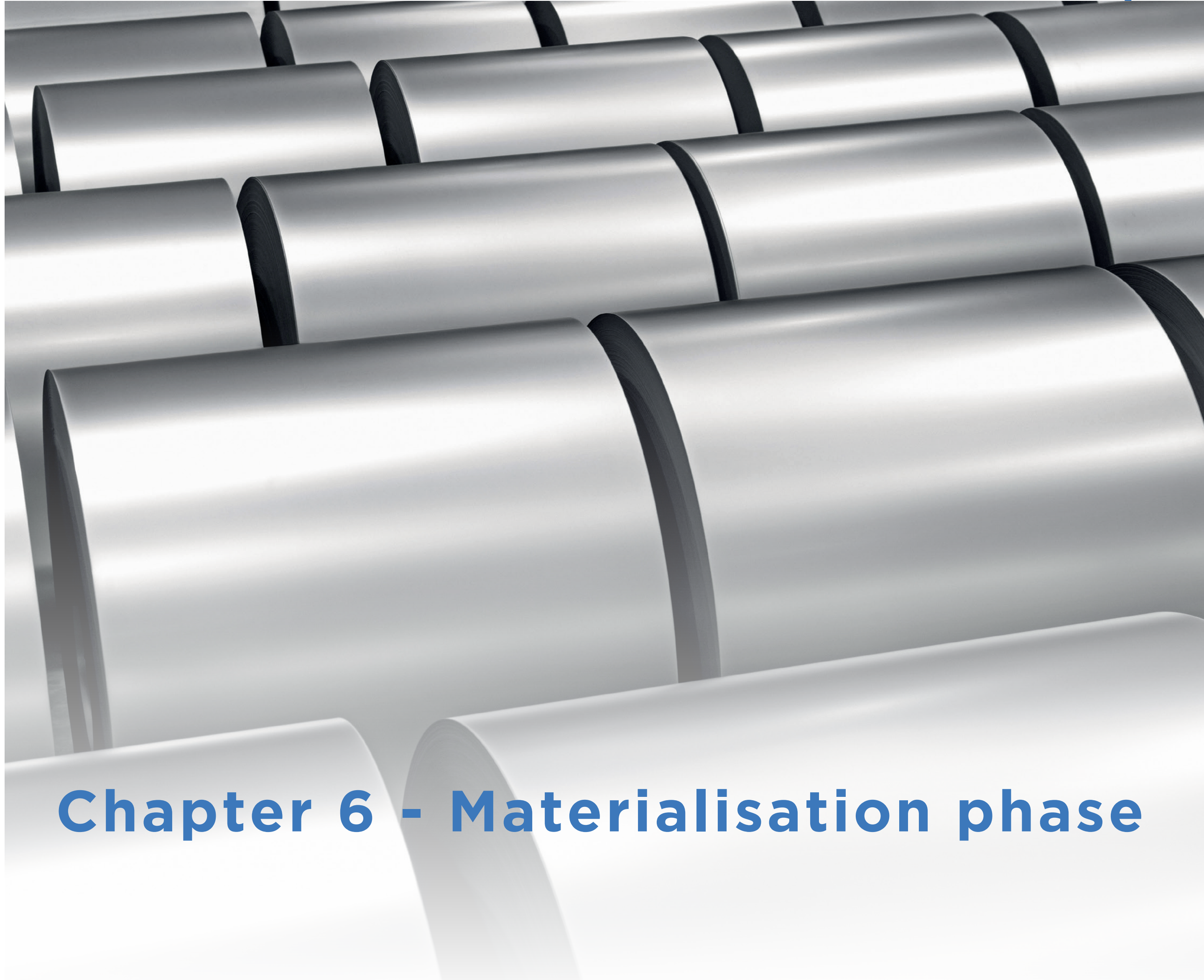
A sleeve was added to the design after material research revealed that PP would be the best option for the coating material. This is primarily due to the fact that PP is less resistant to scratches, which is undesirable. Apart from this PP would be harder to print on. In addition, the incorporation of a sleeve would make it possible for multiple brand owners to utilise the packaging. As the main can would remain unchanged, but the sleeve could be modified per product, this was also the most sustainable option. This ensures that the packaging's logistics remain uncomplicated, as it does not need to be separated before being resent to the brand owners. In addition to concealing scratches and serving as a marketing tool, the sleeve would also conceal dents. This also increases the likelihood that the packaging can be reused multiple times.

The decision was made to fold the sleeve slightly over the edge, as drop tests revealed that the majority of damage from drops occurred at the bottom edge of the packaging.

The fourth research question answered during these phases is.

Is Protact® packaging that can be reused more environmentally friendly than single-use packaging?

To answer this question, a life cycle analysis (LCA) was conducted. This has demonstrated that the Protact packaging is more environmentally friendly than the Quaker Cruesli Luchtig (375g) packaging after seven reuse cycles. To ensure that all effects have a reduced environmental impact, ten reuse cycles should be considered.
Additionally, a plastic cap is preferred over a Protact cap. According to the analysis, using the Protact cap would increase environmental emissions. This result could change if the food product could be stored for a longer period of time with the Protact cap. However, this should be tested before any model modifications are made.



Chapter 6 - Materialisation phase

In this section, the materialisation phase will be discussed in greater detail. This includes the product's intent, appearance, perception, business case and validation.

6.1 Intention

The purpose of the design presented in this thesis is to serve as an illustration of a reusable packaging that can be made from Protact. This example includes a branded sleeve for Quaker Cruesli Luchtig. Nevertheless, this can be any odourless dry food product. The labels should have a distinguishable ribbon to indicate to the consumer that the packaging belongs to a family of reusable packaging (same can, different labels).

The packaging was created with the European market in mind. Considering only breakfast cereal, it is anticipated that this packaging will be sold 500.000 times per year. This is based on the assumption that 1% of the European population consumes breakfast cereal daily and purchases a new box every week. However, since this packaging is also designed for other dry food products, this number will likely be higher. This would result in decreased production costs and ultimately lower consumer prices.

Design for reuse / design for X

The packaging has been designed specifically for reuse. According to the findings of the research phase, there is a greater likelihood of purchase when reusable packaging is less expensive than the single-use alternative and is more convenient. This has also been taken into account when designing the packaging.

Aside from this, the packaging is usable by both left- and right-handed individuals. It would also be possible for colourblind consumers to recognise their favourite foods. Additional features should be added for blind consumers. For instance, adding braille to the sleeve. As the packaging for different products is identical to the touch, a blind person will be unable to distinguish between the various types of food inside without some guidance.

6.2 Aesthetics and perception

A consumer's decision to utilise reusable packaging is influenced by the aesthetics of the packaging. Their decision is primarily influenced by the price of the packaging and the food it contains. Nevertheless, the packaging must be considered clean and safe for use; otherwise, it will not be used.

The desired feeling a consumer to have when looking at the packaging is one of safety. When using the packaging, they must feel secure. In addition to safety, the consumer should also experience convenience when using the packaging.

The aesthetics of the packaging must be robust and solid. As a result, the consumer will feel confident that the packaging can be reused multiple times. The consumer should not perceive that the steel's coating does not protect the food within.

When using the packaging, the consumer must also perceive the connection to sustainability. Since they would reuse the packaging multiple times. It is also essential that consumers understand the benefits of repeatedly reusing packaging. This would increase the likelihood that they would reuse the packaging more than once.

6.3 Business case

The next step in the research is to develop the business case. The business case has been developed to assist with future decisions regarding the implementation of reusable packaging. This section will explain the short-term and long-term strategies, and finally the conclusion. The objective of the project is to successfully implement reusable packaging. While keeping the consumer and ecosystem engaged and interested. Tata Steel can assist with implementation by allowing brand owners and can manufacturers to purchase reusable Protact.

6.3.1 Short-term implementation strategy

The short-term implementation strategy consists of the marketing mix; product, place, price, promotion, and people. The plan will be written for Tata Steel, but will contain information for other stakeholders as well.

Product

The product is the first part of the strategy. The product to be sold by Tata Steel will be a modified version of Protact that aims to increase the product's durability. The reusable version of Protact will be modified by employing a thicker substrate and a double-sided PP coating instead of PET. By using a thicker substrate, these modifications would increase the number of cleaning cycles the product could withstand and reduce the frequency of dents. It is recommended not to increase the profit margin when determining the price of the reusable Protact, as the product could become more expensive for the end user than the single-use version. This would not be favourable because it may discourage consumers from purchasing reusable packaging.

For every stakeholder besides the metal manufacturer (such as can manufacturers and brand owners), the product to be sold is the reusable packaging. This packaging has been designed specifically to increase the user's convenience by incorporating a transparent cap, an easy pour feature, and a robust design. The consumer can use this packaging for a longer duration than, for instance, packaging for single-use breakfast cereal. It is also recommended that the primary packaging include other dry foods, such as pasta and rice, in addition to breakfast cereal. However, dry foods with strong odours should be avoided until it is researched whether the odour remains in the material after it has been cleaned.

By using this packaging for a variety of dry foods, sustainability can be improved, as one type of packaging can be transported without the need for sorting and extra transportation space.

This decision may raise concerns regarding the brand owner's brand image, as this was one of the issues identified in the literature review and interviews. This issue has been resolved by using a sleeve that can be personalised for each brand owner. Even though the sleeve must be recycled after each use, the brand image can still be communicated, as will be demonstrated in the completion phase.

Place

Europe is the location where the reusable packaging will be sold. Initially, a partnership with Loop would be advantageous for the implementation of reusable packaging. As this requires minimal to no change from brand owners and consumers, which is one of the concerns obtained from the research phase. The brand owner must modify their filling line in order for the reusable packaging to fit. It would also be possible to directly contact brand owners who have their own cleaning line and could use it to clean the reusable packaging.

It would be critical to locate the cleaning and filling stations as close as possible to the supermarkets, as this would reduce the amount of pollution caused by transportation. Consequently, there should be smaller, more localised hubs for cleaning in each nation, and depending on the size of the nation, multiple hubs. Figure 50 illustrates the situation in the Netherlands. This would require one cleaning hub as the maximum distances that needs to be travelled would by 190 km. During transportation it is important to ensure that the truck is not travelling without any load, this can be solved by adding reverse logistics. Using an electric truck would be even more beneficial.

Figure 50: Location cleaning and filling hub Netherlands (example)

Price

The product sold in the reusable packaging should not cost more than the product sold in single-use packaging. As this may decrease the consumer's interest. Due to the larger volume of the reusable packaging, the price per kg will be compared. In addition to a price reduction, the addition of features such as a transparent cap and an easy pour should increase the convenience and, consequently, the willingness to purchase.

The suggested selling price is determined by the results of the long-term plan, which will be described next. These prices are determined by the cost of materials, the cost of production, and the stakeholders' profit margins. The price determined for this is €4,39 per 450 g. Comparatively, the single-use packaging containing 375 g costs €3,99. This would reduce the price per kg by €1,16.

Additionally, it is recommended to utilise a deposit system. As it has been demonstrated that it increases the rate of return, as is the case with PET and beer bottles. The deposit system will provide consumers with an incentive to return packaging. This reusable packaging should require a deposit of €1,00, as this amount exceeds the average cost of reusable packaging. When a consumer chooses to keep the packaging, it is possible to produce another without having a financial loss.

Promotion

Currently, the majority of consumers are unaware of the environmental consequences of single-use packaging. This is the first aspect that should be highlighted to consumers, for instance through social media and television advertising. Aware consumers are more likely to reuse packaging when they see the effects on the environment.

When consumers become more accustomed to the concept of reusing packaging, the implementation of reusable packaging will become more seamless. Therefore, it is recommended to hold off on implementing reusable packaging on a larger scale until a greater number of consumers are aware of the benefits and are more likely to purchase. However, it is recommended to begin testing the packaging on a small scale in order to improve the convenience of all types of dry foods and to limit test the amount of cycles it could be used. This would ensure that once the packaging has been implemented, its convenience has been thoroughly evaluated and is high. Apart from that it would also ensure that the packaging is able to be reused at least seven cycles and therefor be more beneficial to the environment. It would also be possible to initiate the promotion to raise awareness of the potential for reusable packaging. By lobbying brand owners and demonstrating the possibilities to them.

When awareness increases, brand owners who have collaborated may begin promoting by advertisements containing their product packaged in reusable packaging. Demonstrating to the consumer their commitment to sustainable packaging and their desire to improve. This will result in favourable brand perceptions and associations.

People

The final component of the sort term-strategy is people. It is crucial for reusable packaging that all parties involved in the reuse cycle collaborate with one another. In order to improve the packaging's sustainability. In order to bring reusable packaging to light, Tata Steel could initiate the conversion with multiple brand owners and can manufacturers. By speaking with multiple brand owners, Tata Steel's involvement and eagerness to assist with the implementation of reusable packaging as a supplier of improved reusable Protact would become apparent.

The product could be sold to anyone desiring to have a more positive impact on the environment, while also benefiting themselves slightly. The product could be used by children as young as 8 years old. As for younger children, dropping the packaging could be painful due to the fact that it is made of steel.

6.3.2 Long-term implementation strategy

A calculation tool has been developed in order to determine the most effective strategy to implement. The tool and its rationale are explained in appendix AQ. This tool compares the single-use packaging of Quaker Cruesli Luchtig with the reusable packaging containing Quaker Cruesli Luchtig. In addition to these two versions, there was a third that compared the ecosystem with and without the use of a refill/return provider. Without it, the brand owner would need to provide reverse logistics and modify their business model, which would necessitate additional changes to the company. Due to the required changes for brand owners and the resulting complications, the version without has not been selected for the short-term strategy. However, in the long-term scenario, this could be chosen once reusable packaging is used more often.

The long-term scenario is one that is projected to occur between 15 and 20 years in the future. As this is also the time when several legislative objectives must be met. Such as the objective of achieving 20% reusable packaging by 2040. Legislation of this nature would also incentivize brand owners to collaborate on the use of reusable packaging within a system.

Figure 51 shows the price per kg based on the amount of reuse cycles. This number indicates that reusable packaging becomes economically viable at €10.49 per kg, after a minimum of two reuse cycles. The lowest possible price per kilogramme is €9.29. While the price per kg of single-use products remains unaltered at €10.49 per kg.

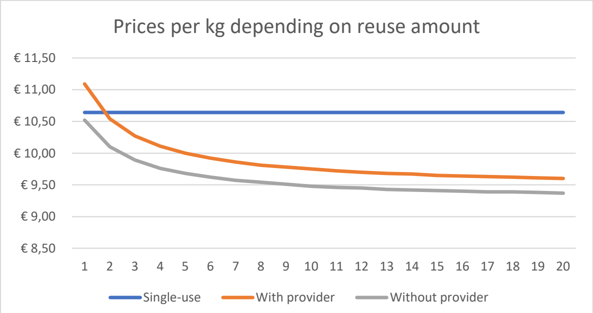


Figure 51: Comparison on price per kg

Comparing the scenario with refill/return provider to the scenario without, it is evident that without would be more advantageous for the consumer, as the price would be lower. However, in this case, the brand owner would be responsible for its own cleaning and logistics, which may become attractive in the future as reusable packaging becomes more widely accepted and utilised.

Changes stakeholders

Participation in a reusable packaging system would be advantageous for nearly all stakeholders. When there are no issues with implementation and the packaging is reused ten times. Metal and can manufacturers are not currently involved in the breakfast cereal or other dry food products. Therefore, they would benefit from packaging being sold in reusable packaging made from steel. Even though this is unlikely to result in a large profit, it would still be interesting because they are entering a new market segment.

6.4 Conclusion business case

Based on the results of the short- and long-term strategies, it would be beneficial to implement reusable packaging as opposed to single-use packaging. As it is possible to significantly reduce material costs when packaging is reused. There are, however, a few situations in which the advice would change, such as if the strategy fails or is successful. The following section will focus on these potential scenarios. These situations arise when reusable packaging is provided in larger quantities.

Successful launch
In the event that the packaging launch is successful and consumers embrace reusable packaging. The plan could remain the same, but brand owners could reduce the cost of their reusable packaging by cleaning and managing logistics themselves. Even more, it would be possible to customise the packaging and create packaging that is unique to their brand. However, this should not result in the elimination of other packaging. The purpose of using reusable packaging is for it to be utilised frequently and not discarded, as the packaging was intended to have a positive impact on the environment.

Medium launch
This is a launch with sufficient consumer interest in purchasing and using the packaging. In this instance, in order to minimise the environmental impact, it would be advisable for a number of brands to change only the branding on the label and not the packaging itself. It is essential to increase the number of consumers who utilise reusable packaging. There could be more advertising highlighting the advantages of reusing packaging, for instance. Or advertisement showing the consumers the effects on the planet when using single-use packaging.

Unsuccessful launch
When the product launch was unsuccessful and consumers remain uninterested in purchasing the product, it is necessary to determine why. In order to relaunch the improved product in the future. It is crucial for the future of our planet that consumers have access to and utilise reusable packaging. However, when this launch fails due to the existence of a successful alternative reusable packaging, the objective is also met. Tata Steel could attempt to collaborate with the alternative manufacturer and suggest the reusable Protact version.

6.5 Product validation

6.5.1 Prototype

During the course of this project, several prototypes were developed. This section displays the final prototype, figure 52. With a white base colour and sleeve.

Figure 52: Final prototype

During the user validation, a version of this prototype was utilised; the packaging was black and didn't have a sleeve. For this validation, ten Tata Steel colleagues were consulted. Due to confidentiality concerns, there were no responses outside of Tata Steel. The setup for user validation can be found in appendix AR. During the validation, participants were instructed to pick up the packaging and pour a portion of its contents into a cup without further guidance. This was done to ensure that they performed the validation without bias. Appendix AS contains the complete validation responses. This section will provide a summary.

The prototype fit well in the hands of both male and female respondents. Aside from this, the majority of respondents (8 out of 10) used the easy pour intuitively, despite the fact that some of them had never seen the packaging before. Two of the ten respondents poured without the easy pour, which resulted in breakfast cereal spillage both times. While this was not the case when easy pour was used.

In conclusion, the design has a good fit, and the easy pour feature enhances convenience by preventing food from spilling on the table or floor. It facilitates the respondents' ability to pour with greater control.

6.5.2 Validation on list of requirements

In this section, the designed reusable packaging and selected system will be evaluated in accordance with the created list of requirements. The list of requirements consists of various types of requirements, some of which cannot be tested at this time and must therefore be tested after a prototype made of metal, for instance, has been created.

Functional requirements
Nineteen of the twenty requirements have been met. Requirement 1.4 must be evaluated using time, as this requirement requires the packaging to preserve food for at least one year. The three wishes have not yet been satisfied. The three wishes are for secondary and tertiary packaging to be reusable. However, this part of the project has not been elaborated upon.

Technical requirements
Twenty-one of the twenty-five technical requirements have been met. The four criteria that were not met necessitate additional research, which will take additional time. Such as whether the secondary packaging containing the primary packaging would survive a one-meter drop without visual damage (2.4). Requirement 2.21 can be evaluated via the vibration tests. One of the three wishes has not been fulfilled. Wish 2.27 can be evaluated with the washing test.

Scenario requirements
Four of the twenty-one requirements were not yet met. All four of these requirements require extensive user research. For example, 3.14 requires that nine out of ten consumers find the packaging to be clean and safe to use. All four wishes have been met.

Ecosystem & consumer requirements
Two of the eighteen requirements have not yet been met. The requirements that have not yet been met need additional research, such as one-year reuse cycles (4.4) and washing tests (4.16). The three wishes have been met.

Material requirements
Three of the twenty-one requirements have not yet been met. This is also due to the need for additional research. The research on washing (5.10 and 5.11) and vibration testing (5.5). The one wish has been met.

Legislation requirements
All 13 requirements have been met. However, it should be noted that additional reusable packaging requirements are likely to be established in the coming years, and this should be considered again when implementing reusable packaging.

In addition, two requirements from Tata Steel were formulated. These are also satisfied. There were also requirements on the list that could not be affected by the packaging design. These requirements should be considered during the implementation of the reusable packaging system.

In conclusion, 88 percent of the requirements have been met. The remaining 12% require further research. These include user questionnaires, vibration testing, and washing testing. After these tasks have been completed, the remaining 12 percent of requirements can be tested. 71% of the wishes have been fulfilled. The remaining 29% also require additional research.

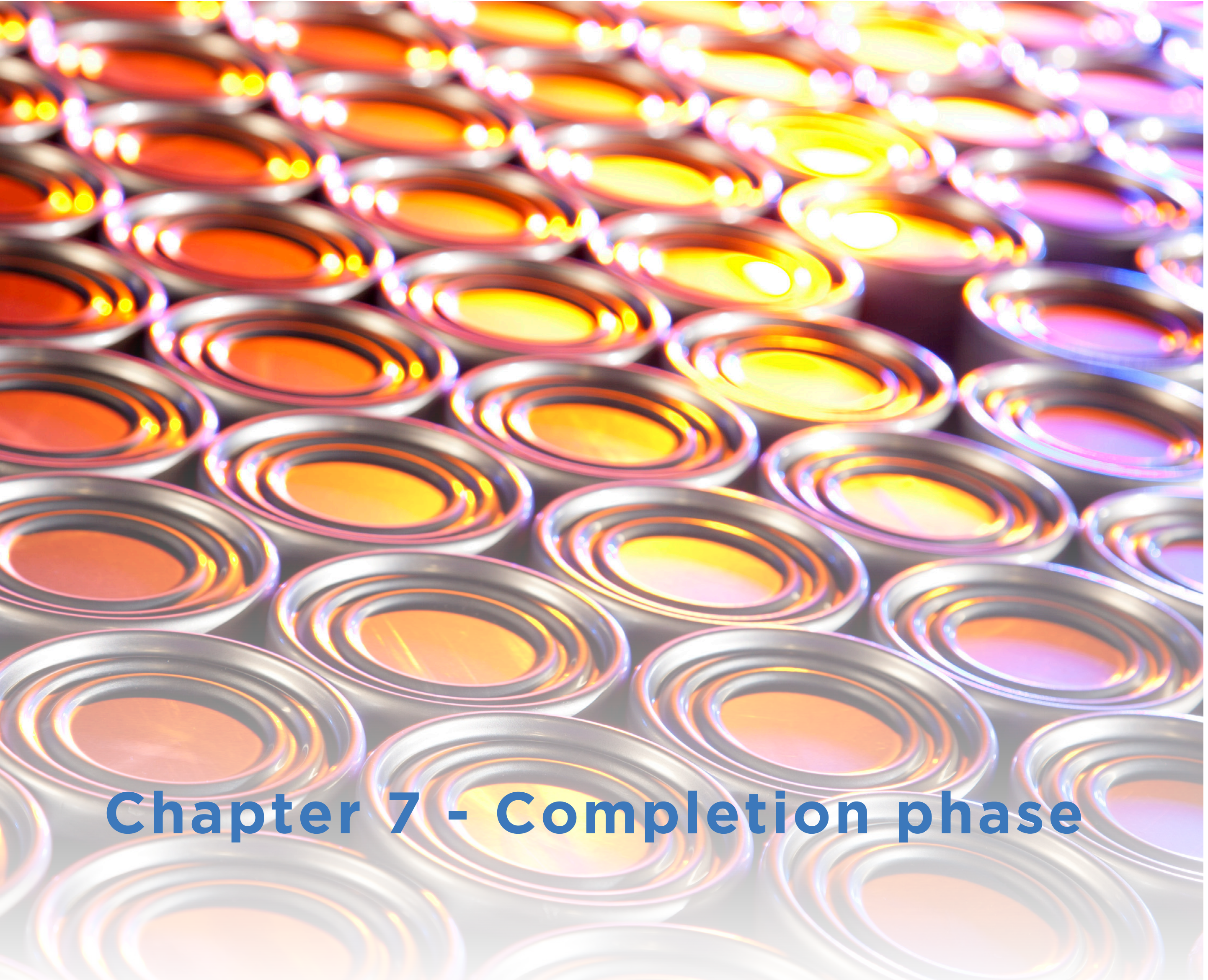
6.6 Conclusion

In this phase, the product's business case have been developed. This demonstrates that the implementation of reusable packaging would be profitable after three reuse cycles. As this is the point at which reusable packaging becomes less expensive per kg than single-use packaging.

On the short term, it is advised to collaborate with Loop or another company that facilitates packaging reuse. As this would require the least amount of brand owner modification. Prior to implementation, small-scale testing must be conducted to ensure that the packaging can be reused at least seven times. When this is not the case, the packaging and/or materials must be modified. By increasing the thickness of the substrate and/or coating, for instance. It is essential to confirm that the packaging is more sustainable than single-use options.

The long-term strategy has shown different scenarios and their corresponding strategies. The most important considerations are the retail packaging's price and the consumer's convenience when reusing the packaging. Aside from this, the experience of purchasing and returning the packaging should be pleasant and should not require the consumer to make any adjustments.

User testing has demonstrated that the final design has an excellent grip and is comfortable to hold. Additionally, the easy pour testing demonstrated that it reduces the frequency of spills and even prevents them. While using the same packaging without an easy pour, spillage has been observed. The validation on the list of requirements revealed that nearly all of the requirements have been met. The requirements that could not be met require further investigation.



Chapter 7 - Completion phase

The completion phase includes alternative sleeve options as well as the placement of the final product in an environment. This will demonstrate what the packaging looks like with different branding on the sleeve and in the intended environment.

7.1 Alternative packaging (with different sleeves)

Figure 53 depicts the alternative sleeve options for the product that are compatible with the reusable packaging. Due to the fact that they are all dry foods that do not leave odours on the material. This also demonstrates the impact of utilising various sleeves on the packaging.

In addition, another illustration was created to depict how they would appear on a website. Albert Hein's website was chosen as an example because some of its stores already offer consumers the option to refill packaging (as a pilot). Figure 54 depicts the website with the four reusable packaging added on the top row.

Figure 53: Alternative sleeve options

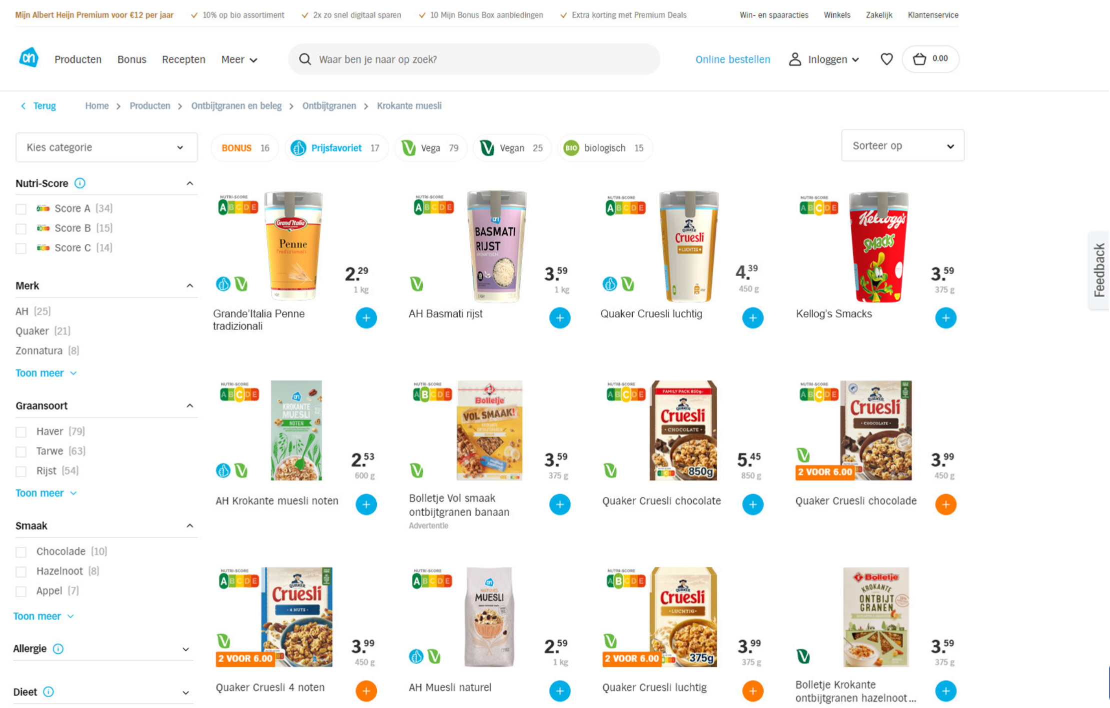


Figure 54: Reusable products in webstore ah.nl

7.2 Product in environment

In this section, two of the previously shown packaging with sleeve will be displayed in its intended retail environment. The Albert Hein supermarket was chosen for this demonstration, for the same reasons listed previously. The packaging is displayed in an area where products for sale that week are placed. It is assumed that reusable packaging is sold in the same manner as single-use packaging, which would also mean that discounts would apply. The only difference for the consumer would be the payment of an additional deposit, which would be refunded upon return of the packaging. Figure 55 depicts the packaging's displayed in a supermarket.

Figure 55: Product in environment (supermarket)

Chapter 8 - Conclusion

In this section, the report's conclusion will be presented. In which the primary question is addressed. The primary question was "Is it possible to design a reusable packaging using Protact®, preferably for the food industry and the European market?"
It is possible to design Protact packaging that is reusable. However, some aspects must be taken into account when designing reusable packaging from Protact. These aspects are:

- Open edges
- Scratch resistance
- Dent resistance
- Printability

When designing reusable Protact packaging, these factors should be considered. As PP's exposed edges, visible scratches, and incapacity to be printed on restrict design freedom. As demonstrated in the report, these restrictions can be mitigated by using a sleeve; only the exposed edges require another approach. This problem can be resolved by injection moulding PP to the edge. Be mindful that the injection-moulded edge and coating should not exceed 5% of the packaging's weight, as this may cause issues with future regulations regarding mono-material packaging. In addition to the specific considerations for designing reusable Protact packaging, there are additional general considerations for designing reusable packaging. These include:

- Cost
- Hygiene
- Convenience
- Brand image
- Logistics
- Traceability

These aspects are listed in order of significance. According to the report, cost is the most essential aspect to consider. The price should not exceed the cost of the packaging for a single use. Even consumers who are unaware of the impact of single-use packaging may opt for reusable packaging if the price is maintained at the same level or is reduced. The reusable packaging and its system should be extremely clean. As any infection caused by the packaging or system may discourage consumers from reusing packaging in the future. Increasing the convenience for consumers when reusing packaging increases the likelihood that they will purchase and return the packaging. The convenience of this design presented in this report has been enhanced by the addition of a pouring assistance and a transparent cap. Importantly, the consumer should be able to identify the brand by looking at the reusable packaging. It is essential to limit the number of various can designs, as this will make logistics and cleaning more difficult. Using a sleeve, it is possible to differentiate between brands while using the same can, as demonstrated in this report.

As the intended food products are dry foods, a distinct shape is unnecessary. When using reusable packaging for cleaning detergents, for instance, it is necessary to use a distinct design, as consumers might otherwise mistake the cleaning detergent for dry food. Logistics is an another important aspect. Given the necessity of reverse logistics, increasing the amount of packaging that can be returned in a single shipment is advantageous for the environment and logistics. This can be accomplished by using tapered designs so that the packaging can be nested (as shown in the report).The final point, traceability, will ensure that the packaging can be traced. This will aid in making the design more durable, as the ecosystem will be able to pinpoint where most packaging are discarded and reduce the amount by implementing changes.

These aspects result in Protact packaging that can be reused. In addition, it ensures that the likelihood of consumers using reusable packaging is maximised. Which is required for the reusable packaging and system to be successful.

Chapter 9 - Discussion & recommendations

This chapter contains the discussion and recommendations. The discussion will primarily centre on factors that must be considered when analysing the results. The recommendations will include multiple aspects that require additional research.

9.1 Discussion

During the project, a number of material researches were planned. In order to ensure that the material can be reused multiple times. The report also includes these plans. Due to a lack of time and resources, it was not possible to carry out two research plans. The required material for the test was Protact with PET and PP. This material was not available in larger quantities, and Tata Steel did not have the necessary equipment to produce the same test cans using this material at the time of the project. This material had previously been used for much smaller cans, so testing was required before creating larger cans from it for which was not enough time. For the water absorption test, therefore, research from colleagues was utilised. While the research was still relevant, there were a few areas that require additional investigation, as will be explained in the recommendations. Due to the fact that Protact PET and PP have only been subjected to a single pasteurisation and sterilisation cycle, it is currently impossible to determine with certainty whether they could withstand the dishwasher cycle multiple times.

The closure testing packaging has been provided by Zaanlandia. It must be stated that it is unknown how frequently the packaging was opened prior to testing. A screw thread is not the only type of closure that could be examined. The final model's snap-fit connection has not been subjected to the same level of testing. The water analysis was conducted using Dutch tap water. When performing the test in various European countries, the results may vary.

In order to continue with the project, it was necessary to make a number of assumptions, which must also be considered. These assumptions were made throughout the business case and life cycle assessment calculations. As it was impossible to know with certainty the profit margins of each stakeholder, assumptions were made. In order to calculate the costs for the food components of the long-term business case, assumptions were also made. The costs were derived from sales prices minus profit margins and estimated material and production costs of single-use packaging. The remaining price served as the price for the food content. Given that the reusable packaging could hold more food than the single-use packaging, it was assumed that the food price would be reduced by 5% to encourage consumers to purchase the larger packaging. In future calculations, the brand owner or other interested party could use the same tool developed for this project to calculate the results, but the required numbers should be adjusted for a more precise result.

Since the validation was conducted by Tata Steel employees, some of them were already familiar with the design which might have caused the results to be biased. A couple of respondents stated that they had never seen the design before, so their responses would be more accurate. In future research, it is recommended to also conduct user validation with consumers from outside the organisation, as well as to ask brand owners and supermarkets what they think of the design and the system.

9.2 Recommendations

In this section, recommendations for future research will be provided. The recommendations are divided into two sections; one for research recommendations and one for design recommendations.

9.2.1 Research recommendations

1. *Supermarket interview*

Several brand owners and can manufacturers were interviewed during the research phase. It was not possible to schedule an interview with a supermarket during the project's duration. It is still advised to conduct additional supermarket interviews. As a result, this may have varying effects on their barriers to introducing reusable packaging. In addition, it will indicate whether they are willing to incorporate reusable packaging into their stores.

2. *Vibration testing coating*

As previously stated, it was not possible to conduct the vibration tests during the project. As PET and PP test packaging were required for these tests. Still, it is recommended to conduct these tests as they will provide insight into the coating's durability. Increasing certain aspects of the coating could increase the coating's durability, thereby decreasing the required sleeve thickness and increasing the amount of reuse cycles.

3. *Washing and drying testing*

A further recommendation is to conduct washing and drying tests. Several options are available, including utilising the setup from Loop or developing a test line for the washing tests. Additionally, it would be useful to determine the minimum time required to clean the packaging. This would reduce the amount of water and detergents required to clean the packaging, particularly because it will contain dry food. Which would benefit its calculated sustainability outcomes.

4. Closure testing above 100 times

The packaging made from PET has been opened and closed up to a 100 times. It would also be necessary to repeat these tests with PP to determine how it reacts to being repeatedly opened and closed. Next, the number of times to open the packaging should be determined based on the average life span of the packaging and the number of times it is determined to be opened in one lifetime. The test should be repeated up to and beyond the minimum number of times required. Apart from this the test should also be repeated with a snap fit opening from PP.

5. Food tainting testing

During the duration of the project, tainted material issues arose. When the reusable packaging is used for different types of dry foods, it is possible to use it for coffee beans one day and breakfast cereal the next. As coffee beans have a potent flavour and aroma, their use could result in tainting. This issue has already been discussed with Campden research institute. Campden is aware of the project and the issues that require solutions.

Campden suggested using triangular testing. A professional testing panel would be presented with three samples, one of which would contain coffee beans and the other two would be empty (and then all three would be cleaned). Then, they would be asked to identify the odd one out, and depending on their response, they would be required to explain why they chose a particular answer. This type of research would yield both quantitative and qualitative findings.

Tata Steel may also use this information for other research purposes. Therefore, it would be advisable to continue the collaboration started with Campden and conduct the research in cooperation with them.

6. Regulations for reusable packaging

The sixth recommendation relates to regulations regarding reusable packaging. At the time of writing this report, there are not yet many regulations related specifically to reusable packaging. This is anticipated to change soon. As more reusable packaging is likely to be introduced in the coming years, additional legislation research is necessary.

In addition, more research should be conducted on the use of mono-material. Currently, mono-material is defined as a composition of 95% of a single material. It is unknown if the coating of Protact also contributes to this percentage. In this instance, the injection-moulded edge of the packaging should be adjusted slightly so that the total amount of PP does not exceed 5%, at this moment the percentage is 5,2%. Furthermore, it should be determined whether reusable packaging must also comply with these regulations, given that it has a much more positive impact than single-use packaging. Furthermore, the addition of the injection-moulded edge could extend the packaging's lifespan by a couple of years because it prevents corrosion.

7. Test total amount of reuse cycles possible

To ensure the success of the packaging, it is essential that the packaging can be reused a minimum of seven times. To accomplish this, small-scale testing should be conducted with the final design made from Protact. On a small scale, it is possible to control the packaging's movement and determine whether seven cycles are feasible for the desired packaging design. With the use of the QR code on the packaging, this could be accounted for.

9.2.2 Design recommendations

8. Adjust embossing location (higher)

The packaging's embossing for nesting and sleeve attachment must be modified slightly. When the packaging is nested, it is possible to push the packaging above the embossing point with sufficient force; in this case, the packaging remains attached to the other packaging and requires greater force to separate. This issue could be resolved by increasing the width of the embossing and elevating it slightly. Depending on the final packaging dimensions. Figure 56 shows the adjusted embossing height. The bottom edge should be low enough to end-up underneath the embossing, to ensure there is little change of the upper edge to go over the embossing.

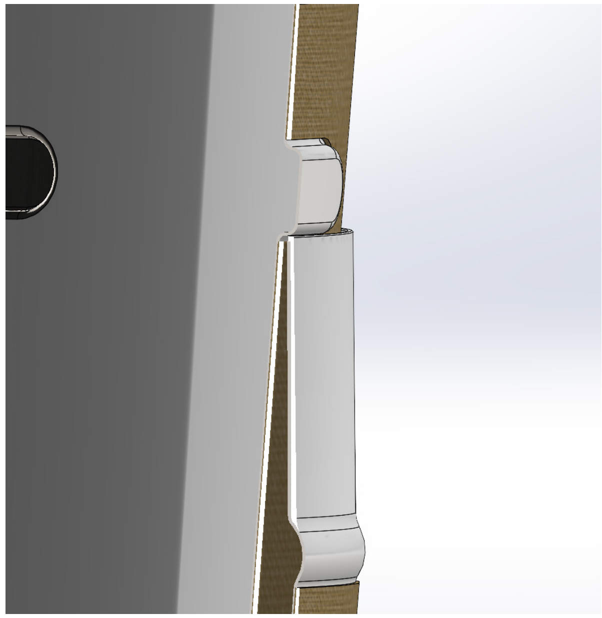


Figure 56: Final model v.5 for recommendations

9. Add another embossing

At this moment two embossing's are placed on the packaging in order to prevent the packaging from getting stuck together when nested. However, it has been noticed that when the embossing is twisted that way it ends up in the easy pour opening the packaging still get stuck together. In order to prevent this from happening another embossing should be added. Preferably on the back side of the packaging. On the front would also be possible but this would be less aesthetically pleasing. Figure 57 illustrates what this would look like.

Figure 57: Final model v.5 back side (additional embossing)

Chapter 10 - Evaluation & reflection

In this chapter the evaluation and reflection of the project will be given.

10.1 Evaluation project

The project began in September. Because the supervisor was on vacation for two more weeks, the first two weeks were performed from home. However, the project was started in order to gather background information on the company and the reusability topic. During the first few weeks, preliminary planning was completed in order to structurally begin the project (appendix AT shows the planning), which was also evaluated by the supervisor. The research phase began in the following weeks. Following the completion of the background research, the preparation for the interviews and material research began. Because of the time required to gather respondents for the interview and perform the material research (and gather the materials required for the tests), this was created immediately after. Soon after, it became clear that gathering the respondents and material took even longer than anticipated for. The first material research was conducted using materials that were already available at the time, these were used for the drop test and microscopic research. At the same time, interviews were conducted, and findings from other studies were discussed.

The supervisor assigned to the project left Tata Steel in the middle of the research phase, requiring a change in supervisor. Since this happened, the development of the business case has been carried out earlier. As the supervisor possessed extensive expertise in this field. The business case was improved and adjusted with the correct information at a later date.

The following phase was the design phase. The material research was not completed during this phase. The washing and vibration tests had to wait because they required materials that were not available at the time. Apart from this information about the washing process was not provided yet as there were issues with the NDA between Tata Steel and Loop. By this time, the interviews had already been conducted; however, this took longer than expected because setting up interviews with brand owners was more difficult than anticipated for. Despite the lack of washing research, the design phase could still proceed. Which went as planned and did not take any longer than anticipated at beginning. As was also the case with gathering respondents for the concept choice.

The detailing phase came after that. This phase also went as planned. The sustainability calculation took a little longer than expected, but there was still enough time to complete this section successfully. The final step was to place the packaging in its environment and show what the packaging would look with different sleeve branding. This, too, went as planned. Except for the fact that the material research could not be completed entirely due to material shortages and a lack of time for the material to arrive, the majority of the project was performed without any issues.

10.2 Evaluation own performance

Throughout the project, experience with working in a larger company was gained. It was difficult to focus for 40 hours per week during the first few weeks. After a few weeks, the decision was made to try a different type of study method. This is known as the pomodoro technique. The working time is divided into smaller chunks using this method. Work for 30 minutes, then take a 5-minute break before working for another 30 minutes. Focusing for shorter periods of time with smaller breaks increased focus time throughout the entire day. This increased productivity significantly, especially during the first few weeks of the project. The further along the project, the less time was required to fill. Working for a couple of hours without being interrupted by distractions became more of a habit. This is a positive side effect of working 40 hours per week for several weeks, as this is also required after graduation.

A plan was created at the start of the project to ensure that the focus was on the end goal. Even when the plans had to be modified a few times. The project was completed on time and with few delays. The only chance that has caused a minor setback has been the chance in supervisor. A new supervisor had to be assigned to the project and become acquainted with it. The first few months of information had to be shown again. In comparison to the previous supervisor, the new supervisor's time available for guidance was limited because he did not initially have the project assigned to him. When assistance was required, however, time was made available and assistance was provided. Whenever a question arose, it could be directed to either of the two supervisors, depending on the nature of the question.

During the project, there were two or three weekly update meetings where the supervisors were shown the project's progress. This resulted in valuable feedback about the project. This could be used to improve the project's outcome. As a result, the project results were more accurate.

10.3 Reflection

Looking back on the project, I learned a lot while having fun at the same time. This project's topic was very interesting, and I believe it will become even more relevant in the future. As a result, I believe I could assist future businesses in becoming more sustainable and responsible.

During this project, I learned how large corporations operate. The company is divided into several smaller sections, each with a specialist in a specific area. As a result, talking to different people was extremely beneficial. You must do so, for example, in order to speak with the appropriate people who can assist you.

Using spectroscopic technologies such as Raman was something I was unfamiliar with previously. I had never heard of the possibility of determining the material composition using these types of techniques before coming to Tata Steel. This information does not have to be useful for future products, but at the very least I know there are possibilities for determining material specific information when needed, and I also know some specific information about those technologies. For that I am very grateful.

Another new aspect that I needed to work on was setting up and conducting material research. Prior to the master, I had never conducted any material-related research. It was fascinating to hear from colleagues about the best ways to do so. Throughout the project, I also requested feedback from several colleagues on every aspect of the project in order to validate the process that was chosen. This was also very helpful, and it helped to improve the project.

I am very pleased with the outcome presented in this report. I believe the end result could be a solution to the current issues presented in this project. I tried to address as many issues as possible when implementing reusable packaging, and I believe I did so successfully.

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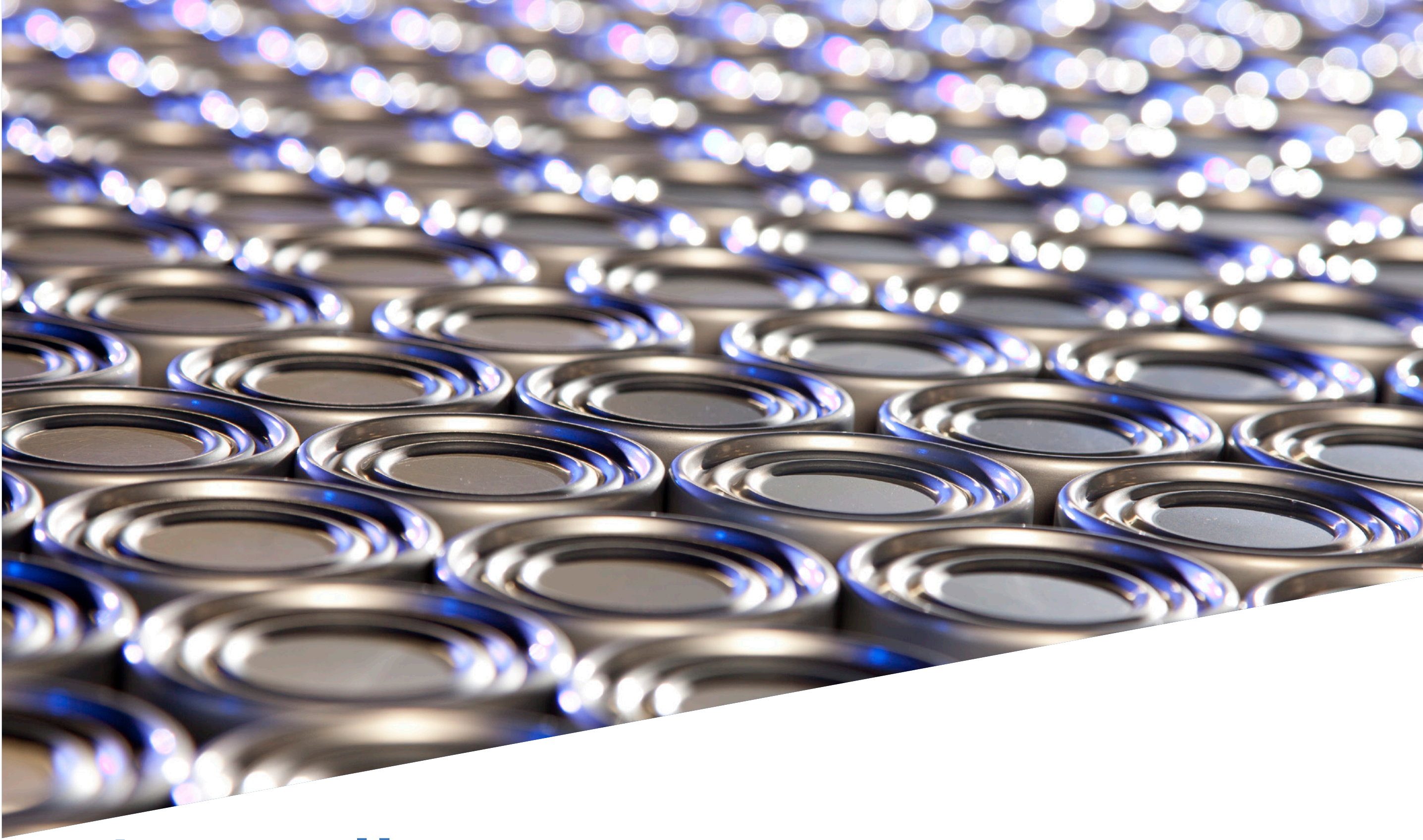

Appendix

The Future of Packaging: Evaluating Protact® for Reusable Packaging

This thesis report presents a comprehensive material analysis and reusability assessment of Protact®, evaluating the feasibility of Protact® in achieving reusable packaging. Including a reusable packaging design and guidelines for implementation.

Master thesis - DPM 2019
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Appendix A – Supermarket exploration AH with refill section

An observation has been performed at AH XL, Gelderlandplein in Amsterdam. In order to determine how they have chosen to implement a refill section. Which system and refillable packaging did they use? Figure 1 depicts an impression of the store.

Figure 1: Impression of AH XL refill section

The first thing that came to light was that the AH's reusable packaging was made of plastic and was extremely lightweight. This makes them simple to transport and return. However, consumers were not restricted to the store's refillable packaging; they could also refill their own containers.

There was a wide variety of refillable products available. All of the goods appeared to be dry food. The filling and buying process of this reuse system has not been simulated. As returning the packaging was quite impractical.

The aisle was clearly divided, the information was clear, and the colours used were earthy. Possibly because recycling benefits the environment. The emphasis is on utilising wood or brown hues, with the occasional use of blue from AH branding.

This investigation gave a good impression of how a refuelling station could appear. There are no statistics on how well the products are selling or whether anyone is using them. That would have been extremely useful.

Appendix B - Material used in packaging

The packaging materials are summarised in table 1.

Table 1: Collection of packaging materials [A1]

Materials	Sub materials
Glass	Sand Lime and soda Borosilicate
Metal	Aluminium Laminates and metallized films Tinplate Tin-free steel Stainless steels
Plastics	Polyofind (PE and PP) Polyester (PET and PETE) Polyvinyl chloride (PVC) Polystyrene Polyamide (Nylon) Ethylene vinyl alcohol (EVOH) Laminates and co-extrusions
Paper	Kraft paper Sulphite paper Greaseproof paper Glassine Parchment paper Paper laminates
Paperboard	White board Solid board Chipboard Fibreboard
Wood	Wood Jutes Ceramics Biodegradable materials

Appendix C – Full comparison materials

This appendix contains the complete Excel spreadsheet from the competition analysis.

The comparison sheet of material properties can be found in table 2.

Table 2: Material properties comparison [A2,A8,A9]

Kolom1	Sources	Steel (used in Protact)	Stainless steel	Aluminium	Glass	Plastic	Paper & paperboard
Strength	Granta - Tensile strenght/density	0,092	0,072	0,070	0,013	0,037	0,021
Elasticity	Granta - Yield strength (MPa)	433,0	257,0	118,0	31,0	37,3	15,0
Fragility (fracture thoughness)	Granta - Fracture thoughness (MPa.m^0,5)	33	57	23	0,64	7,31	5
Shelf life	[1]	Years	Years	Years	Months/years	Weeks/months	
Permeability (UV, water and gasses)	Granta - Durability (UV, water and gasses)	13	15	14	15	9	4
Transparency	Granta - Transparency	Opaque	Opaque	Opaque	Transparent	Opaque/transparent	Opaque
Weight (density)	Granta - Density (kg/m^3)	7800	7610	2650	2440	1071,67	700
Magnetic	[10,11,12]	Yes	Mostly, not all	No	No	No	No

The comparison based on the material converted into packaging can be found in table 3.

Table 3: Packaging comparison [A3,A4,A5,A6,A7,A23,26,27]

Kolom1	Sources	Steel (used in Protact)	Stainless steel	Aluminium	Glass	Plastic	Paper & paperboard
Contribution to the market	[2]	12,20%	12,20%	12,20%	6,60%	41,50%	35,70%
Recycling rate (packaging)	[3,4,5,6,7]	70,0%	80%	76%	76%	27%	68%
Costs (total costs of packaging)	[2]	€€€€	€€€€	€€€€	€€€	€	€€
Reused material at the moment?	[8,9]	No	Yes	Yes	Yes	No	No

Appendix D – Consumer research

To determine what consumers prefer in terms of reusable products, consumer research was conducted. This research aims to determine what consumers' benefits and barriers are, as well as what would motivate them to change their behaviour. The consumer research has been conducted through a review of the relevant literature. The first section of the consumer research consists of findings from previously conducted studies on the same topic. The second section discusses additional studies concerning sustainable or reusable packaging.

Previously executed studies

Seven studies are discussed in this section. These studies are relevant to the topic because they investigate not only consumers' willingness to pay for reusable packaging, but also the barriers that prevent them from doing so.

S. C. Greenwood et al. [42] have conducted the first study. This research was conducted to determine consumer participation in reuse systems. 276 adults currently living in the United Kingdom participated in the survey.

When asked what they would be willing to do with packaging for various products, this study reveals that recycling (53%) is the most frequently chosen option. The second-best option was to dispose of the packaging in a garbage can (34%). Only 13% of respondents chose to reuse. This indicates that respondents are more familiar with recycling than with reuse, as recycling has been an internationally accepted practise since [14]. When respondents did choose to reuse packaging, refilling and repurposing were the most popular options. Only 1% of respondents would return the packaging to the retailer.

The respondents were also asked which type of material they were most willing to reuse. This led to the creation of a list of 13 materials, including biscuits in a metal tin, milk in a glass bottle, coffee in a glass jar, cleaning sprays, and hand wash in plastic bottles. 37% of respondents were more inclined to reuse glass packaging. Material, packaging type, and closure mechanism all have a significant impact on people's willingness to reuse. When it comes to reusing packaging, the method of dispensing, the packaging's ease of opening, and the presence or absence of a window are irrelevant.

Aspects of packaging that encourage reuse are its resistance to change over time, its durability, and its ease of cleaning. When designing a new reusable packaging, these factors should also be considered.

G. Pretner et al. [44] examine the consumers' willingness to pay (WTP) for circular products, specifically clothing. Even though this may not be the same as the food segment, some of the findings from this study may still be relevant. This study utilised an online survey and received 2300 completed responses.

According to their research, consumers are unwilling to pay more for circular products. They are perceived as having lower values than the new version of the same product. However, the WTP increases when consumers are shown the product's environmental benefits.

Reused or recycled clothing has characteristics such as previous use, contamination, and a higher risk. Even if the garments have a positive environmental impact, consumers are concerned that something has happened to them and are uncertain that they are clean and undamaged.

The research also demonstrates that garment labels such as "recycled" have no effect on the WTP. As the environmental characteristics are already obvious, consumers do not require verification. If consumers are already environmentally conscious, they will always be more willing to pay more for sustainable products.

According to the study, these findings can also be directly extended to other products that come into direct contact with the human body, such as foods. In this instance, the fact that a product is recycled has no greater impact on its evaluation than the product's specifications.

Another study conducted by the World Economic Forum in collaboration with Kearney examined the impact of Covid-19 on consumer behaviour regarding sustainable packaging [23]. The research also concentrated on opportunities and challenges for reuse systems.

They discovered that 48% of consumers are more environmentally conscious than before Covid-19. 55% of respondents indicated they were more likely to purchase environmentally friendly products.

Respondents insist on the increased use of reduced packaging, which makes them more environmentally friendly. People are increasingly purchasing in bulk and rejecting single-use plastic packaging.

Convenience is crucial to the success of a reuse system, as consumers with limited time place a premium on it. To increase the use of reuse systems, a number of obstacles must also be overcome. Convenience and affordability are two of them, but so are packaging safety, inadequate infrastructure, financial viability, and brand differentiation.

When a reuse system is implemented, the value in the supply chain shifts, as the value is no longer with the material but rather with the later stages of the product (reusing the packaging).

Accenture conducted the following research [43]. This research is also concerned with changes in consumer behaviour regarding sustainable packaging over the past few years. This survey-based study included 6000 respondents from 11 countries across North America, Europe, and Asia.

Consumers' primary concerns with packaging are its cost and quality (89% and 84%, respectively). However, 83% of respondents believe that it is extremely important for businesses to design reusable products. 72% of respondents indicate that they are purchasing more environmentally friendly products than they did five years ago, and 81% anticipate purchasing more in the next five years.

Plastic packaging is thought to be the least environmentally friendly type of packaging (77%). While 55% of respondents believe that paper is the most environmentally friendly material.

We-pack [57] conducted a smaller study to determine whether or not consumers are currently attempting to reuse packaging. They also looked at the respondents' age and gender, which produced some interesting findings. They gathered their data through a survey, with 1023 responses from people currently residing in the United Kingdom.

The results indicate that 48.6% of respondents are currently reusing packaging on their own behalf. Reusing packaging like jars, vases, and refilling empty bottles. 5,7% of respondents say they reuse packaging because they think it will save them money in the long run. 4.8% of respondents indicated that they discard the packaging they use. While some (13.1%) claimed that reuse consumes too much space.

Interestingly, female respondents scored higher on the reuse portion of the survey, whereas male respondents scored higher on the disposal and non-reuse portion. 26.5% of respondents who stated that reuse saves money are between the ages of 25 and 34.

This study demonstrates that consumers are familiar with and have engaged in reuse throughout their lives. However, this does not account for the possibility of reusing store packaging or refilling packaging in-store.

The following study has the greatest number of respondents and thus appears to be more credible. This research has been performed by Trivium conducted by Boston Consulting Group, which is one of the metal packaging manufacturers in the Netherlands [38]. Which report responses from 15620 consumers in the United States, Europe, and South America.

According to this study, 67% of consumers consider themselves environmentally conscious. Additionally, 74% are willing to pay more for sustainable packaging. However, the percentage increase that they are willing to pay is not substantial. As 27% are only willing to pay $0.25 to $0.50 more for packaging worth $10. And 22% are willing to pay an additional $0.50 to $1.00. 25% of consumers are willing to pay an additional 10% for sustainable packaging.

Consumers are also less likely to purchase packaging with harmful ingredients (58%). Metal is thought to be less harmful to the environment than plastic. 65% of respondents link plastic packaging to ocean pollution. In addition, 53% of consumers actively seek recycling logos on packaging.

According to the research, the growth rate of sustainably marketed products was 5.6 times that of non-sustainable products.

Hubbub [47] conducted the most recent research. This study interviewed forty organisations and surveyed three thousand people. They investigated what factors would promote the growth and success of reuse systems.

According to the research, 73% of people in the United Kingdom believe that more should be done to make it easier to choose reusable over single-use alternatives.

In a survey of 3000 consumers, 41% said that if there were no additional costs associated with reusable packaging, they would reuse packaging more frequently. Rewards or discounts, according to 38%, would persuade them. Understanding that the packaging would be more environmentally friendly was also influential (38%). The accessibility of programmes in their neighbourhood also had a significant impact (34%). The final factor that would encourage consumers to reuse packaging is that they would not have to make an extra effort to do so.

38% of consumers do not use reusable packaging due to hygiene concerns. Another is that it might be more expensive (31%). Having to carry the packaging and the possibility of forgetting to bring the packaging are also significant influences (27% and 26%). The final reason cited by 26% of respondents for not using reusable packaging is that it can be scratched, stained, or damaged.

Sixty-seven percent of consumers were willing to borrow and return reusable grocery packaging. Which 45% preferred to do in person at the supermarket, 32% preferred home delivery, and 20% would not use it for groceries.

Sustainable and/or reusable studies

Recent research indicates that deposit systems have a positive impact on reuse system return rates [51,53]. A deposit system typically has a much higher return rate. Even if the economic costs of reusable packaging are higher, for instance as a result of complex logistics, well-organized implementation may still result in cost savings [16]. According to research conducted by Chonhenchob and Signh [15,16], reusable containers that are tailored to the product may decrease the likelihood that it will be damaged or lost.

Awareness, motivation, and social behaviour can significantly impact consumers' selection of reusable packaging [42, 50, 45]. They may be impacted by the inconvenience of returning reusable packaging, the convenience of refillable packaging, the risk of unavailability of refills, the initial costs (which may be higher for parent packaging and deposit system), ineffective communication, cleanliness, quality, and poor pricing policies [51,16,45]. However, they can also be positively affected by the knowledge that they are not harming the environment, reduced costs, price incentives, increased product customization, and the ability to receive product delivery at their doorstep [51,52]. Even though some of these may be contradictory, it depends on the context in which they are used.

Although research indicates that consumers are willing to reuse more frequently, not many consumers are actually doing so at this time [42]. From the standpoint of purchasing reusable packaging from a store. The primary reason given is that reuse options are frequently far from their homes. Perceptions of the effect required to reuse also play a significant role in determining whether consumers will reuse or not [48,49].

Packaging eco-friendliness has also become an important factor in consumer decision-making [39,40,41]. However, they are not as important as price and packaging quality [46], as stated in the previous section. Ocean connectivity may also increase consumers' willingness to reuse packaging, as consumers with a greater awareness of ocean pollution are more likely to reuse packaging [30]. It appears that a preference for sustainable packaging is based on ecological beliefs and attitudes; this indicates that there is a link between environmental concerns and the purchase of recyclable packaging [30,54]. Furthermore, recycle logos were associated with greater positivity than packaging without recycle logos [55]. The material from which the packaging is made is also significant, as consumers are more likely to recognise the material than a logo [56].

Appendix E – Customer journeys

This section will examine the customer journey for multiple reuse systems. In addition, the customer journey of the current system will be compared to the new situations. The four reuse systems outlined by the Ellen MacArthur Foundation serve as the foundation for the customer journeys [1]. The customer journeys will reveal which components of the reuse systems are effective and which are cause for concern. After all, the entire launch will fail if consumers do not use the reusable packaging and system.

The first customer journey is for single-use packaging. The customer journey is shown in Figure 2. As shown in the graph, there are no significant disadvantages to using this type of packaging. Because the product is inexpensive and requires little effort from the consumer, the convenience is high. The decision to use single-use packaging was made in the decision section. Consequently, this is the most important consideration when selecting an alternative.

Stage	Awareness	Consideration	Decision			Service		Loyalty
Customer activity	Visits store or online store	Searches for desired product	Finds product and buys the least expensive option	Pays for the product	Takes product home	Uses product	Product is empty and packaging is thrown away	Buys the same product again
Customer experience								
Customer toughts			This product is very affordable, it is however worse for the environment	The product is quite affordable, the packaging has no value	It is light weight and easy to take home	Packaging does not any additional functionalities that I could use	I will just throw away packaging, since it has no value	I might buy another brand this time to try difference
Customer expectations				Easy to discard packaging after using product			Packaging is going to be recycled	Other brands are just as good
State of packaging	Full	Full	Full	Full	Full	Semi full	Empty	Full

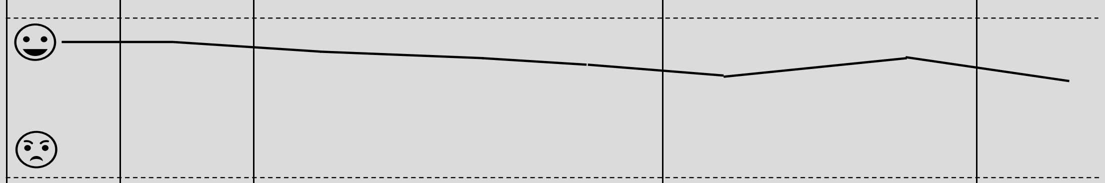


Figure 2: Customer journey single-use packaging

Figure 3 depicts the next customer journey from the refill at home reuse system. In this system, the consumer owns the packaging and must therefore pay a higher initial price for reusable packaging. As shown in the graph, this section also provides a poorer customer experience. Since the customer owns the parent packaging, they will need to purchase refills in-store or online, which also slightly lowers their level of satisfaction. The point at which the original packaging must be discarded (throwing away the insert is another pain point but not as much as throwing away the parent packaging). Since the packaging has value because the consumer paid for it, discarding it is not a pleasant experience; therefore, the customer experience is reduced in that section.

Stage	Awareness	Consideration	Decision			Service			Loyalty		
Customer activity	Visits store or online store	Searches for desired product	Finds product and decides to take the reusable parent packaging (which includes one refill)	Pays for the product	Takes product home	Uses product	Product is empty and insert is thrown away	Goes grocery shopping and also buys another refill	Refills parent packaging again	After several reuses the parent packaging is no longer usable	The entire packaging is thrown away
Customer experience											
Customer toughts			It is nice that this product is not made out of plastic	The product seem quite expensive, in the long run I will save money	This is no different from buying a normal product		Customer realises it will have to buy a refill soon	The refill is small and easy (and cheaper) to take with you while doing grocery shopping.	Refilling parent packaging is easy!	I have to dispose of this packaging in a proper way	I need to throw away expensive packaging
Customer expectations			Using this product decreases future ocean waste	Expects the product to last for a long while			Getting a refill should not be to difficult			Expects there to be a return point for the parent packaging.	
State of packaging	Full	Full	Full	Full	Full	Semi full	Empty	Empty	Full	Semi full	Empty

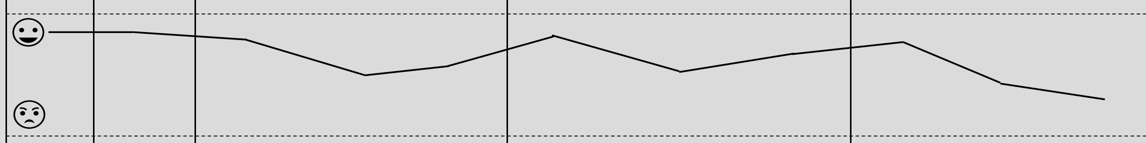


Figure 3: Customer journey refill at home

Another customer journey has been made of the refill on the go reuse system, figure 4. In this system, the consumer is also the owner of the packaging and will be required to bring it with them the next time they go grocery shopping. As with refill at home, the most difficult aspect of this journey is paying a higher price for reusable packaging. Another aspect of this reuse system is that the customer must bring the reusable packaging back to the grocery store. In addition, discarding valuable packaging is problematic in this reuse system.

Stage	Awareness	Consideration	Decision			Service			Loyalty		
Customer activity	Visits store	Searches for desired product	Finds product and buys the product in a refillable packaging	Pays for the product and packaging	Takes product home	Uses product	Product is empty and needs to be refilled	Goes grocery shopping and brings the refillable packaging	Refills packaging	Uses product again and needs to refill regularly	The packaging is thrown away to be recycled
Customer experience											
Customer toughts			Choice was difficult since single-use is less expensive	Eventhough initail purchase is expensive eventually I will save money	This is no different from buying a normal product	This product looks good and is easy to use	I have to bring the empty packaging to the store. Do not forget!		It takes a bit more effort refilling but the expenses are lower		I need to throw away expensive packaging
Customer expectations			Using this product decreases future ocean waste	Expects the product to last for a long while			Getting a refill should not be to difficult	Refilling should be cheaper than single-use			
State of packaging	Full	Full	Full	Full	Full	Semi full	Empty	Empty	Full	Semi full	Empty

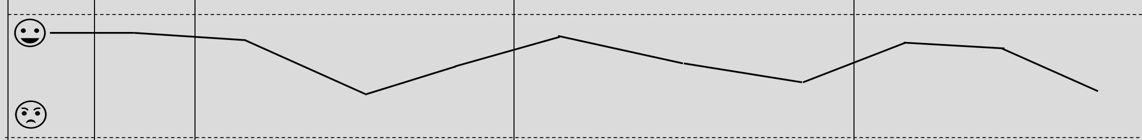


Figure 4: Customer journey refill on to go

Figure 5 depicts the fourth customer journey created for the return from home reuse system. This appears to be the customer journey with the fewest obstacles. As this reuse system is extremely convenient. The only difference may be that the consumer pays the same or slightly more for the product. The packaging is owned by the manufacturer, who handles defects, so the consumer is not required to discard it. From the producer's perspective, despite the fact that this customer journey is extremely convenient, a great deal must be arranged prior to product delivery to the homes.

Stage	Awareness	Consideration	Decision			Service			Loyalty		
Customer activity	Orders product online	Searches for desired product	Finds product and buys the product in a refillable packaging	Pays for the product	Products gets deliverd to the door	Uses product	Product is empty and needs to be refilled	Orders filled reusable packaging	With delivery the consumers also returns the used packaging	Uses product again, buys several filled reusable cans (online)	Improper packaging is discarded into the system, consumer does not notice
Customer experience											
Customer toughts			Choice was difficult since single-use is less expensive	Product is equally expensive but with other benefits, so i'll take it. I am a bit worried about cleanliness though	It is nice that I do not have to get out of my way to be more sustainable	This product looks good and is easy to use	Now I can simply buy a new reused packaging online		Buying a filled reused packaging online is easier than regular shopping, returning is even easier than return on the go		I do not have to throw away expensive packaging
Customer expectations			Using this product decreases future ocean waste	Expects the product to last for a long while			Getting a refill should not be to difficult	Refilling should be cheaper than single-use			
State of packaging	Full	Full	Full	Full	Full	Semi full	Empty	Empty	Full	Semi full	Empty

Figure 5: Customer journey return from home

The return on the go reuse system is the final customer journey created, as shown in Figure 6. In this system, the producer also owns the packaging. This system is less convenient for consumers, but it could be more advantageous for producers (as it requires less logistics). The disadvantages of this reuse system are an increased or constant price for the product and the requirement to return the packaging to the store.

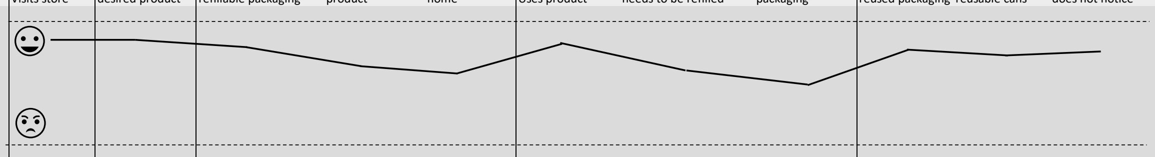
Stage	Awareness	Consideration	Decision			Service			Loyalty		
Customer activity	Visits store	Searches for desired product	Finds product and buys the product in a refillable packaging	Pays for the product	Takes product home	Uses product	Product is empty and needs to be refilled	Goes grocery shopping and brings the refillable packaging	Buys filled reused packaging, and returns empty reused packaging	Uses product again, buys several filled reusable cans	Improper packaging is discarded into the system, consumer does not notice
Customer experience											
Customer toughts			Choice was difficult since single-use is less expensive	Product is equally expensive but with other benefits, so i'll take it. I am a bit worried about cleanliness though	This product is heavier than the single-use packaging	This product looks good and is easy to use	I have to bring the empty packaging to the store. Do not forget!		Buying a filled reused packaging is no different from regular shopping		I do not have to throw away expensive packaging
Customer expectations			Using this product decreases future ocean waste	Expects the product to last for a long while			Getting a refill should not be to difficult	Refilling should be cheaper than single-use			Expects there to be a return point for the parent packaging.
State of packaging	Full	Full	Full	Full	Full	Semi full	Empty	Empty	Full	Semi full	Empty

Figure 6: Customer journey return on to go

Consequently, when considering the various customer journeys, return from home and single-use packaging are the most convenient for consumers. Refill at home and refill on the go are less expensive over time, but they will eventually have to throw away the packaging. Return on the go could fit into the lifestyles of many consumers, as they already go to the grocery store to purchase their goods. However, remembering to bring reusable packaging presents challenges. For the producer, return on the go is the best option because they do not have to arrange the logistics and they can request a deposit to ensure that consumers return the packaging. They would still be required to provide a location for the return of empty, reusable packaging.

Appendix F – Interview questions & answers

The interview questions are listed in this appendix. To avoid confusion when posing the questions, the key questions were listed on a PowerPoint slide. The questions can be found in the list below. They were divided into four categories: brand, reuse system, product, and behaviour. These sections were chosen in order to group the questions and ensure their coherence.

List of questions

Brand:

- Do you currently own any reusable packaging? Why / Why not?
  - o If you already own reusable packaging which product is that and do you plan on expanding your reusable portfolio?
  - o Do you think this is important?
- What are the biggest challenges your brand would face implementing a reusable packaging?
  - o What aspects of your current system would need to change to implement reuse system?
- When you are implementing reusable packaging which aspects are the most important for your brand?
  - o For example brand recognition, price, quality, convenience for consumer etc
- Are your retailers open to adding reusable packaging into their stores? If so why or why not?
  - o Is it important for your retailers to have reusable packaging in their stores?
  - o What challenges are there for your retailers implementing reusable packaging?
  - o Are there differences between retailers?

Reuse system

- Would your brand be willing to invest in a reusable packaging and system?
  - o Would you be willing to work together with other companies to arrange reusable solutions?
  - o How fast would you want your return on investment?
  - o What percentage would you be willing to invest compared to the return your receive of the reusable packaging?
- Do you have the capability to provide the reverse logistic for the reusable packaging?
  - o Would you have to collaborate with another company?
- Logistic wise would it be necessary for the return packaging to be able to be stacked together? So it takes up less space? Why?
- Which reuse system would be the more beneficial to your retailers/your brand?
  - o Return from home
  - o Return on the go
  - o Refill from home
  - o Refill on the go
  - o Does this differ based on retailer?
- Which of these aspect are the most important? Investment, logistics,

Product:

- Would it be beneficial to your brand to include tracing (using RIFD for example) into the reusable packaging? (So you are able to know exactly how often the packaging is reused and were it broke down)
- Do you think the price of a reusable packaging will be higher or lower compared to the single-use alternative?
  - o Do you think the price could become lower with good tracing possibilities?
  - o Would you accept a higher price for a reusable packaging?
- Would you rather prefer one universal design for several products, but with different labelling, or for every product a different design?
  - o Do you think adding extra functionality has added benefits?

Behaviour:

- What do you think is the biggest hurdle for your customers to use reusable packaging?
- Would a reusable packaging be discarded when there are scratches on the inside or outside of the packaging? And why?
- Do you think consumers would accept imperfect (appearance) packaging when it is reusable?
  - o In term of scratches or dent?
  - o Does the location of the scratches/dents matter?
  - o What is the acceptance level of damage can regarding to reusable can?

show powerpoint acceptability of dents

Questions for each slide:

- Would you accept this dent for a reusable packaging?
  - o If so, how many of these dents may be on the can before it would not be accepted anymore

The answers to the six interviews can be found on the following pages. The first responses come from an interview with Reckitt, a brand owner. He is the packaging sustainability director in the hygiene business unit, conducted this interview. Due to time constraints, this interview has been condensed.

Do you currently own/market any reusable packaging? Why/why not?
Loop has launched reusable stainless steel cans in Tesco in the U.K. The packaging is free of plastic and highly recyclable.

What are the biggest challenges your brand faces implementing a reusable packaging?
Several challenges exist, as the systems are still in their early stages of development. Another issue is that the scale is very small, and consumer readiness is still developing. It is a very small business, especially when compared to businesses that sell millions of products in the U.S. Reusable packaging is expected to increase in share. They had no problems with cleaning because Loop handled the packaging cleaning for them. The difficulty is determining how to track the number of cycles that the packaging will go through. You can have mechanical or visual coding on the product so that it can be scanned but rather tracked. However, you should keep in mind that the label or other item placed on top of the packaging does not dissolve in the dishwasher or during the packaging cycle.

When your are implementing reusable packaging which aspects are the most important for your brand?
How frequently do you reuse the packaging, what is the normal use cycle, and what is the shelf turnover? How frequently will the consumer purchase your product? We sell products that consumers keep in their cabinets for a long time. For example, if the packaging for dishwasher tablets remains in the cabinet for 6 months, 10 cycles would take 60 months. This is not viable as reusable packaging because there are so many things that can go wrong with it during this time that it is difficult to survive 10 reuse cycles. The benefits of refilling and reusing decrease as products are used by the consumer for a longer period of time; for food, this is preferable. The product's identity is also critical; the consumer must be able to recognise the brand and packaging. Typically, reusable packaging has standard types, which eliminates some brand-specific experiences. The colour is important brand language because it is recognisable and guides customers to the product (there are also emotional aspects).

Do you have the capability to provide the reverse logistics for the reusable packaging?
In our case, Loop handles this.

Logistic wise would it be necessary for the return packaging to be able to be stacked together?
There are several types of stacked or nested packaging currently available on the market. Reusable packaging does not require stacking, but it may be necessary when considering sustainability (carbon footprint, etc.). This may be necessary if stacking the packaging saves so much space that it significantly reduces the carbon footprint.

Would it be beneficial to your brand to include tracing into the reusable packaging? And why?
This would be advantageous, particularly in the case of a very thin plate steel. Any drop will result in a dent and a drop in quality. U don't know when it happened or how many drops there were if there is no tracing. The tracing could be crucial in determining where the packaging was dented and when it could no longer be used.

Would your rather prefer one universal design for several product, but with different labelling or for every product a different design? And why?
It would be preferable to have one and complexity to zero for sustainability. Smaller stock keeping units mean you don't need as large a warehouse. But brand differentiation would be extremely limited. You also need to make sure that the packaging for, say, vanish is not the same as the packaging for, say, food cookies. This could result in consumers misidentifying the product and purchasing the incorrect product, which could have serious consequences. As a consumer, yo u require recognition for specific product categories.

Is it important for your consumers to have reusable packaging?
There is some interest, but it needs to grow. Small batch products from a specific region would provide the most benefits.

Do you think consumers would accept imperfect packaging when it is reusable?
If they become accustomed to it, they may begin to accept it. This may come as a surprise to consumers at first, as dented/scratched packaging will appear odd. PET bottles are reused multiple times in Germany, even if the damage to the bottle is significant; consumers accept these as well after becoming accustomed to them. It lacks elastic appeal. They will eventually accept it, but they must adapt to it. When a customer sees a dented can in the supermarket, they will choose the one that is not dented. Those dented cans are probably not going to be bought by you.

The following responses are from an interview with Unilever. Who works in Unilever's Knorr section. The answers to the questions are then specific to Knorr rather than Unilever as a whole. The entire interview has been recorded and can be requested if necessary.

Do you currently own reusable packaging?
Knorr currently does not have any reusable packaging. However, there have been attempts to find reusable solutions. They tried options with refills in store, but that did not work because hygiene issues were a real issue.

What are the biggest challenges trying to implement reusable packaging?
The most important issue is hygiene; for the business to be profitable, there must be a profit. Logistics is also an issue (if you're talking about a concept separate from Loop), as it must be organised in a cost-effective manner. Another consideration is consumer convenience. Consumers who use Knorr meal kits, in particular, want efficient and convenient packaging/product that also considers disposal of the product. When consumers snack, they make trade-offs and do not consider factors such as sustainability. The most serious issue with food products is hygiene.

Another reason for the invention of packaging was to prevent theft. With this refillable system, there will be less controlled situations for consumers to take advantage of.

When developing a reuse system and packaging, the three most important factors to consider are hygiene, logistics, and convenience.

Are your retailers open to adding reusable packaging into their stores?
Carrefour was the retailer with whom they tried a refillable solution.

Hygiene is also a major concern for the retailer.

Would the brand be willing to invest in a reusable packaging/system?
He is not in a position to say so, but he believes that every FMCG company would be willing to invest if they could see a return on investment. It must be profitable. The sustainability journey has been communicated to Knorr, so they are willing to invest.

Do you have the capability to provide reverse logistics?
No, they will have to work with other companies to make this happen.

Does the packaging need to be stackable (like cups)?
Yes, for reusable packaging, this is critical; all packaging must be stacked. Because it is the most efficient.

Which reuse system would be more beneficial to your retailer/brand?
He does not have a specific answer to this question. It is determined by the type of product. It is always a matter of which is more convenient. It also depends on how much the consumer is willing to pay for it.

Would it be beneficial for your brand to include tracing into the packaging?
Yes, because this would provide more consumer insights into packaging usage.

Do you think the price of reusable packaging will be higher or lower compared to single-use alternative?
At the moment, yes. When the packaging is traced, he is unsure whether it is possible to lower the price; he is unable to say.

Do you think your consumers would accept a higher price for the reusable packaging?
They do not. Perhaps they would be willing to pay a few cents more. But we must also compete with our competitors; if they sell for less, we must as well. We must strive to please nearly all of our customers.

There is always one aspect of food that is more important than packaging. Which is the flavour of the food .Nobody will buy it if the taste is bad and the packaging is good. They do not sell packaging; rather, they sell food. They sell items that make it easier for customers to prepare food.

Is it easier to launch a reusable packaging using existing portfolio or would it be easier to market them in new portfolio?
The business of innovation is a difficult one to be in. It is generally easier to convert their core portfolio to sustainability.

Would you rather have one universal design for several product but with different labelling or for every product a different design?
The supply chain would say everything the same, but marketing would prefer everything to be different. There are already products in our portfolio that use the same packaging, but the artwork must be different. Some other businesses use the same packaging but with different artwork.

Is it important for the reusable packaging to be similar to the single-use alternative?
It does not have to be identical. There is a lot that can be done with colour and artwork.

What is the biggest hurdle for consumers?
The most important factor would be convenience.

Would a reusable packaging be discarded when there are scratches on the inside or outside of the packaging?
He doesn't know for sure, but he does have an opinion. He would still use it if the packaging was still tightly sealed and there were no holes. However, he is unsure about scratches.

Do you think consumers would accept imperfect packaging when it is reusable?
They have not conducted any research in this area. But, in his opinion, if you have a hole or something similar, that is unacceptable.

The section that follows discusses the acceptability of dents. This section contains images of dented cans. Starting with small dents and progressing to larger ones.

He refused to buy any of the cans. As a consumer, he would not buy it if it had any dents. This could also be related to his background in packaging. As he stated, dents in cans could lead to defects on the inside of the packaging, so he could no longer trust the packaging to be safe.

Friesland Campina was the next brand owner interviewed. The interview was conducted with someone who works as a packaging developer for Friesland Campina. He works on specialised nutrition projects. Specifically designed for metal packaging. For a wide variety of Friesland Campina products.

Do you currently own reusable packaging? Why/why not?
We have, indeed. The packaging is mostly made of glass in the Belgian market. Because glass is overengineered, it can be cleaned and refilled. Belgium has closed chains, making it easier to collect all packaging, and the country is relatively small.

We also have small PET bottles, but they are all one-time use only. Business-to-business reuse is becoming more popular.

Because the company exports a large portion of its products, implementing reusable packaging is more difficult. You must also be able to return the packaging.

The legal requirements for specialised nutrition are much higher. Because the hygiene standards are so high in these areas, reusable packaging is extremely difficult to achieve.

What are the biggest challenges your brand would face implementing a reusable packaging?
Food safety and hygiene must be of the highest priority. There is legislation in the works that will require businesses to create reusable packaging in the near future. The deposit on the aluminium cans is good because it ensures that we get clear aluminium (with no other materials mixed through it).

The cost of (reverse) logistics is also critical.

Another significant challenge is counterfeiting. Particularly in China, where other companies could replicate the product at a much lower cost and sell it in the packaging used for the 'expensive' Friesland Campina. They must be certain that whatever they are purchasing is indeed from Friesland Campina. They require evidence of temper.

Brand recognition is another critical factor. The consumer must be able to identify the brand.

When you are implementing reusable packaging which aspects are the most important for your brand?
Hygiene/food safety, logistics and counterfeit.

Are your retailer open to adding reusable packaging into their stores?
The regulation will require them to eventually include reusable packaging in their stores. The supermarket will have to provide reusable options to customers.

We did a project a while back where we removed the plastic bottle from the packaging. To reduce the amount of materials used in our packaging. This project, however, failed because the consumer lost convenience and the competition did not change anything. As a result, the consumer chose the options that were more convenient for them.

The government should make sure that the rules are the same for all competitors in a given market. As a result, these changes can be implemented. Because consumers prefer convenience and lower prices, the government should lead the change.

Quality degradation must be considered during the reuse cycle. Is the consumer still interested in purchasing it after it has been dented? This should also be researched.

Consider how many bacteria are still present after cleaning. What is clean enough, and how thoroughly does the packaging need to be cleaned? (This can even differ between countries). Another consideration is the time between cleaning and filling the packaging, which should be as short as possible because bacteria may enter the packaging after it has been cleaned, or does it need to be cleaned right before the filling process again.

Would your brand be willing to invest in a reusable packaging and system?
I believe so. Ultimately, it comes down to whether the market wants it, and we still need to make a profit. It will be difficult to reuse. With single-use, you can be certain that all packaging is clean. It is determined by the type of business case used.

Do you have the capability to provide the reverse logistics for the reusable packaging?
We'll have to work with another company to make that happen. They open and clean their own boxes. They want as little time as possible between cleaning and filling.

Metal packaging has a shelf life of one to three years. Is the reusable packaging also capable of having a shelf life of more than a year.

Logistic wise would it be necessary for the return packaging to be able to be stacked together? So it takes up less space?
Yes. One of the most inefficient aspects of metal packaging is its large footprint. The making of the can and the filling of the can occur concurrently. Metal cans take up a lot of space when stored, so being able to stack them together would be a good solution.

The range of filling and return may be affected by the number of cans that can be transported at once. It will broaden the scope of the reuse system. Which could be significant when determining profitability.

Which reuse system would be the most beneficial to your retailer/your brand?
We are not interested in refilling from home. Depending on the product, on-the-go refilling may be possible. The majority of our products are exported. It may be difficult to refill on the go.

Returning home is much more feasible for us. Returning on the go might also work.

The option depends on the type of product and where it is sold. This reuse model may be more appealing if the product is manufactured and sold in the same or a nearby country.

Compare single-use vs. reusable metal packaging. It might be more interesting to select a product that is not currently made of metal and try to reuse it. Rather than reusing a product that is already made of metal.

PET bottles, for example, are manufactured and sold in Europe. Currently, metal packaging is not required. Because it does not need to be transported across entire continents, it does not require a long shelf life or to be as durable. However, when reusing packaging, metal packaging may be useful in this case. Metal packaging, for example, may be durable enough to withstand multiple cycles in Europe.

Would it be beneficial to your brand to include tracing into the packaging?
Yes, I believe so. We have already included QR codes at this time. As a result, customers can see where the product comes from.

With the speed of the production line, RFID may be difficult. Does it withstand 10-20 cycles of pasteurisation, for example? It must also withstand the moisture and heat of the cleaning process.

Friesland Campina currently owns the majority of the eco system. They design their own packaging and clean it. Another company handles collection. Their system is dubbed "from grass to glass."

Do you think the price of a reusable packaging will be higher or lower compared to the single-use alternative?
It is believed that reuse will be less expensive, but convenience will take precedence. To be cheap, you need a large scale and efficiency. When all packaging are the same, the packaging can be very cheap.

Would you rather prefer one universal design for several products, but with different labelling, or for every product a different design?
Each product should have a unique design, according to the marketer. The ideal would be a single design for all milk in Europe, but this is extremely difficult to achieve. You need to strike a balance between universal design and the ability to differentiate your design.

The more types of packaging you have, the more installation you need to clean and separate, and so on. Henri Ford was a good example because there wasn't much else. One type of packaging is the most affordable, but do we want it?

Friesland Campina is looking for a specific bottle. Brands must be specific, while other brands require different brand images. However, Friesland Campina products may be the same design with different labelling. That would be the bare minimum from the marketeer.

Is it important for your consumers to have reusable packaging?
I believe so, but they are probably unaware of it. There is a difference in the acceptability of reusable packaging across continents. I believe that if the reuse system is maintained on the European continent, consumers will be more willing to reuse packaging.

What do you think is the biggest hurdle for your consumers to use reusable packaging?
The most difficult challenge for this generation is the required change in consumer behaviour. It's also important to be able to sustain the changes you're making. Another barrier is the packaging's hygiene.

Do you think consumers would accept imperfect packaging when it is reusable?
Perhaps you require a design that conceals dents and scratches. This could be a specific shape or graphic that ensures the differences between new and reused are not visible.

Perhaps you should design packaging with dents and scratches as part of the design. As a result, they are not readily apparent to the consumer.

A straight can could pose a problem because minor differences would be visible. You must determine the source of the damage to the packaging and add additional protection. A label may also conceal scratches and dents.

The next section is about acceptance of dents
Dent acceptance is determined by the type of packaging. Every ding and scratch will be visible if the packaging is printed.

The first dents are acceptable as long as you have a sleeve to conceal them.

Which dents are acceptable in terms of appearance and which are acceptable in terms of functionality? Dents on the bead may jeopardise the structural integrity of the packaging.

The second dent may be acceptable with a sleeve, but it is functionally weaker and would most likely not survive transportation with several cans on top of it.

Even with a sleeve, the large dent is unacceptable. The visual, emotional, and functional aspects of the packaging can be compared. If any of these are excessive, the packaging will be rejected. The large dent cannot be concealed with a sleeve because the consumer can see the oval packaging and feel where the dent is.

The corner dent could be structurally and visually acceptable. Perhaps you can also conceal this.

To conceal the flaws, you'll need something with a sleeve. Cans should be as strong as possible while also being aesthetically pleasing. Because the sleeve can be added after the product has been filled, the packaging could be used for other types of products as well.

Bonduelle conducted the next interview via email, and the questions were answered.

Do you currently own/market any reusable packaging? Why / Why not?
We currently have only one jar range in France, which is in the reusable schemes within LOOP = we began this project as a Test & Learn to our B Pact Commitments " 10% of our packaging designed to be recyclable or reusable"

What are the biggest challenges your brand would face implementing a reusable packaging?
To ensure that the reusable packaging is suitable for food contact after cleaning, as well as to have a robust packaging that can be reused multiple times and thus have a lower environmental impact than single-use packaging.

When you are implementing reusable packaging which aspects are the most important for your brand?
As previously stated = food safety, robust enough not to break during the reusable schemes

Are your retailers open to adding reusable packaging into their stores? If so why or why not ?
Yes, as long as the cost of the product is close to that of a single-use product; unfortunately, most distributors are not yet ready or open to a reusable mentality.

Would your brand be willing to invest in a reusable packaging and system?
Yes, and metallic packaging could be an excellent solution.

Do you have the capability to provide the reverse logistic for the reusable packaging?
No, it should be done by a third-party company.

Logistic wise would it be necessary for the return packaging to be able to be stacked together? So it takes up less space?
Yes, ideally, if we want to minimise the environmental impact of the logistics chain as much as possible.

Which reuse system would be the more beneficial to your retailers/your brand?
I would say the following concept Refill on the go & Return on the go.

Would it be beneficial to your brand to include tracing (using RIFD for example) into the reusable packaging?
Yes.

And why? (So you are able to know exactly how often the packaging is reused and were it broke down)
Exactly for the number of cycles that package did and thus evaluate the entire LCA (Life Cycle Assessment) of the packaging, which could be useful for quality reasons (traceability on process, cleaning....)

Do you think the price of a reusable packaging will be higher or lower compared to the single-use alternative?
When the deposit is returned to the consumer, I believe it should be equal.

Would you rather prefer one universal design for several products, but with different labelling, or for every product a different design? And why?
To keep things simple and cost-effective, I'd rather use a single reusable design with different labels to differentiate the product.

Is it important for your consumers to have reusable packaging?
It is critical for environmentally conscious consumers who are willing to return the packaging.

What do you think is the biggest hurdle for your customers to use reusable packaging?
Price and deposit to advance, effort to return the packaging, doubt if it is truly environmentally friendly, product food safety= has the packaging been thoroughly cleaned before reuse?

Would reusable packaging be discarded when there are scratches on the inside or outside of the packaging? And why?
It should not be assumed that we will educate our customers that it is only a cosmetic flaw and that they will accept it; additionally, we must confirm that there will be no impact on robustness and food safety.

Do you think consumers would accept imperfect (appearance) packaging when it is reusable?
Personally, I believe that, but it all depends on the imperfect appearance, we should establish some acceptance standards.

The following interview was with a manufacturer of cans. This is Trivium.

Do you currently produce reusable packaging?
At the moment, these are aluminium reusable bottles that the consumer owns. You buy it full and reuse it until you no longer need it. We also have hand soap bottles that can be replenished at the supermarket. These two reuse models help them legally because they are not liable for dents that occur after the consumer purchases the packaging. Currently, the packaging is made of aluminium, which is better for moisture environments. They also get questions from customers about reusable packaging, which is frequently requested (it is something that is alive).

Do you think it is important to have reusable packaging?
Yes, if it makes sense. You don't want to create much heavier packaging that is reusable but is discarded before use. There is always the risk that consumers will not reuse the packaging; if it is specifically designed for reuse, the changes are greater, the packaging is heavier, and it will cause more environmental issues if discarded after one use. Trivium has traditionally focused on recycling. Because recycling consumes far less energy than using virgin materials. They are still committed to this decision, but reusable materials can be investigated, and they are willing to do so.

Which changes need to be made to your company to make reusable packaging possible?
It is primarily a new stock keeping unit within the company (SKU). And modifications if they use Protact®, as this is a different process than the current packaging, which uses the coating line. There are no drastic changes. The majority of changes are with the clients (brand owners). We need to look at material applications, and Protact® could be useful. The disadvantage is that Protact® is made of plastic and not entirely of metal.

What are the disadvantages of implementing reusable packaging?
As claims increase, so does the risk. There are no problems with single-use systems because they are cleaned and used only once. When they are reused, there is a greater risk of damage and consumer claims. Another disadvantage is that you sell fewer items. However, this is dependent on how you implement it; perhaps raise the price so that the packaging can still be created. In this case, another business model is required.

Would it also be okay if the amount of packaging decreases but the amount of profit stays the same?
Yes, if the business model is changed in such a way that it is still beneficial to create the packaging.

What are the advantages?
The two most important are changes to the environmental burden and marketing purposes. It is beneficial to market products as environmentally friendly. It may be interesting to alter the business model; it does not have to be detrimental. You have consumer buy-in (mostly due to brand owner benefits), and they will refill with the same product.

Which production techniques are possible in your company, also the ones that are more out of the box?
They use currently available production techniques. These include three-piece, DRD, DWI, and impact extrusion. Take a look at Ivo Ten Brinck's powerpoint. This powerpoint describes all of Trivium's production techniques, along with their benefits and drawbacks.

We can produce different shapes, but it will come at the expense of production speed.

Are their specific types of shapes that are difficult to produce?
This is determined by the techniques used. Typically, shaping is done from the inside out. Take a look at Powerpoint.

How hard it is to produce a new design?
It is not that simple. You cannot simply produce something using 3D printing, for example. The initial investment is substantial. You must ensure that the packaging can be manufactured. It would be preferable to set up a test line to simulate packaging production.

Symmetric shapes are the most desirable. If it is not symmetric, it will be as the cost of the packaging's strength. You must ensure that the packaging is strong enough to withstand sterilisation.

You should also examine the packaging's openings. With reusable, new openings are possible; this would be more difficult but not impossible.

Would the company be willing to invest in tools etc needed to produce reusable packaging?
Yes, they would. However, the investment must be repaid within a reasonable time frame. There should be no downside for them. Everyone is willing to invest as long as they can make a profit in a reasonable amount of time.

The final interview is with a can manufacturer as well. Zaanlandia, a small-scale can manufacturer, is the company. They produce a wide range of packaging, as well as specialty packaging (made per order). They manufacture the packaging in both the Netherlands and China. Depending on the nature of the request.

Do you currently produce reusable packaging?
Yes, but primarily through consumer-owned reusable packaging. We make cookie cans, for example, which are reused multiple times in consumers' homes.

Cans are reused for various purposes in developing countries.

Do you think it is important to have reusable packaging?
Yes, it is crucial. Especially for the generations to come. We must protect the environment.

What changes are needed to your company when implementing reusable packaging?
This would make little difference to us. Because the packaging produced at this time is already being reused by the consumer. They produce in smaller quantities, and reusable packaging is available upon request. They are already producing a variety of packaging, so changing something is already possible. If new equipment is required, they will have to invest.

What are the advantages of implementing reusable packaging?
The benefits for them are similar to those of implementing other packaging. They don't make a lot of them. The benefits do not belong to him; they belong to brand owners, for example.

What are the disadvantages of implementing reusable packaging?
As previously stated, there is not much that needs to be changed for them because the packaging they produce at the moment is already reused by the consumer. The only disadvantage is that if the product cannot be produced at this time, they will have to invest in this tooling.

Which production techniques are possible within the company?
The majority of production techniques are for 3P cans. But, DRD, they also make some 2P cans. However, our 2P can capabilities are limited; we can only produce 24mm deep cans with 2P. They have a lot of options with 3P.

Are there specific shapes that are not possible to produce?
Their facility has limitations, but they can hire other companies to produce shapes that he cannot produce.

How hard is it to implement a new design?
We always strive to produce outside of our usual parameters. They want to know what is possible, what the material and tooling allow for. A new design could be a standard can with a screw thread.

Would your company be willing to invest in new tooling etc to produce reusable packaging?
Yes, if it would benefit our company or be required by the outside world, it would be well worth the effort. It does not have to be profitable; we also owe it to future generations.

Appendix G - Other relevant production techniques

As the material Protact® is delivered in sheet format, it is important to understand all possible sheet metal production techniques before visiting metal packaging manufacturers. GRANTA EduPack was utilised to determine all possible options. This application maintains a database of all existing materials and manufacturing processes. The sheet production techniques are of interest for this assignment. Each possibility will be briefly described below.

Deep drawing

This is the most common form of sheet formation. Depending on the size of the die, this method may be costly or inexpensive. In this method, a die and a tool-steel punch are utilised. The metal is permanently deformed by being punched into the die. Due to the necessity of understanding the limits of metal bending, a final shape can rarely be created with a single die and requires more. Figure 7 depicts a flowchart of the deep drawing procedure.

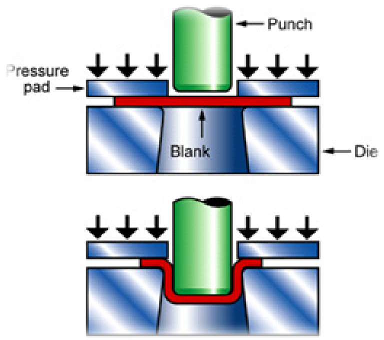


Figure 7: Schematic deep deepdrawing

Electromagnetic forming (EMF)

Electromagnetic forming (EMF) This technique utilised intense magnetic pulses to accelerate the workpiece at a die or joining part. It is capable of high precision and production rates. There are three types of electromagnetic fields: compression, expansion, and shape-forming. This method is typically utilised for tubular metal. However, it can also be used to create simple shapes from a flat sheet. A diagram of electromagnetic fields can be seen in figure 8.

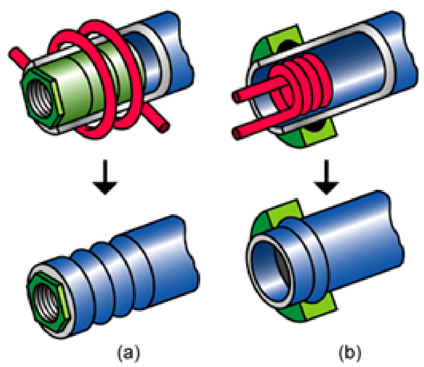


Figure 8: Schematic EMF

Explosive forming

This method employs a die and explosive charge. The charge is sufficient to bend the metal sheet into the die. This method is appropriate for very large parts (with a diameter up to 6 m). However, production rates are low and labour expenses are high. A schematic of explosive formation is depicted in figure 9.

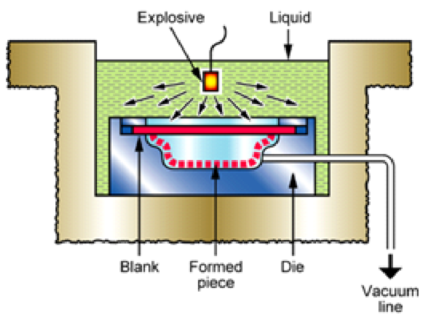


Figure 9: Schematic explosive forming

Micro-blanking

This is a miniature form of blanking. It has high precision and is only used for cutting out shapes. Electro discharging is used to manufacture the die in order to ensure its accuracy. A diagram of micro-blanking can be found in figure 10.

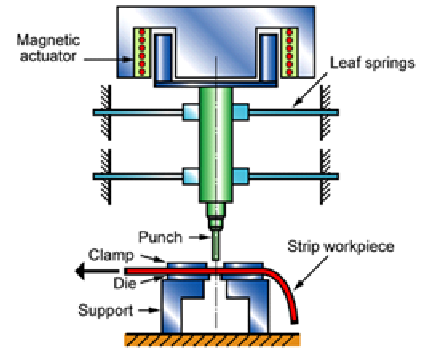


Figure 10: Schematic micro-blanking

Press forming / stamping

Press forming incorporates an array of metal deformation techniques. In this category are blanking, shearing, drawing, bending, forming, coining, and swaging. These processes can be performed sequentially to create intricate shapes. Because each product requires a unique set of tools, the cost of tooling is substantial. Figure 11 depicts a schematic of press forming.

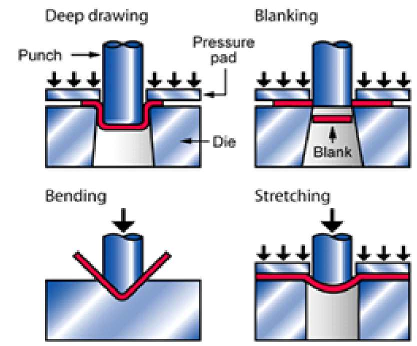


Figure 11: Schematic press forming

Roll forming

Roll forming is a continuous process that can consist of multiple steps to achieve the desired result. A sheet strip is passed through a series of rolls. Welding enables the production of hollow tubes. The high production rate makes this process economically advantageous. A diagram of roll forming can be found in figure 12.

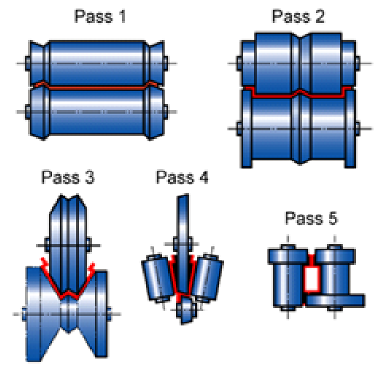


Figure 12: Schematic roll forming

Sheet hydroforming

As the name implies, water is used in this process to press sheet metal into a die. This is performed under intense pressure. Multiple parts can be made from a single blank, which is an advantage of this process. However, cycle times are shorter than in mass production. Complex forms can be created in a single step. A diagram of sheet hydroforming can be found in figure 13.

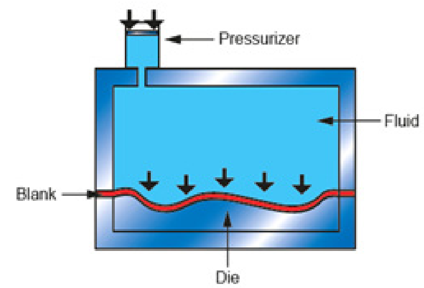


Figure 13: Schematic sheet hydroforming

Spinning
In spinning, a metal sheet is placed inside a rotating machine and pressed against a die. The sheet is then gradually formed by pressing it into the die. Since the tooling costs are low, smaller batch sizes are more attractive. Not applicable for complex shapes; they must be cylindrical. Figure 14 shows an schematic of spinning.

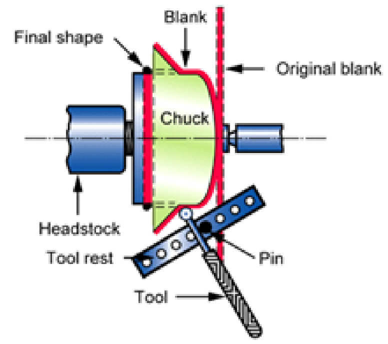


Figure 14: Schematic spinning

Superplastic forming
In this process, the metal is heated to precise temperatures before being formed. This method is only applicable to metals with exceptional plasticity. The combined processes used are thermoforming and blow moulding. Deep or complex shapes are possible, holes are not possible. Figure 15 depicts a diagram of superplastic deformation.

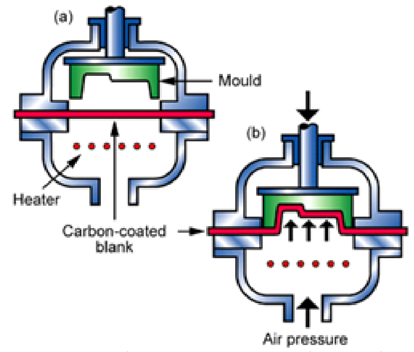


Figure 15: Schematic superplastic forming

As the product to be designed for this assignment is packaging, not all of these production methods for sheet metal are applicable. Because, for instance, they are designed for large components or take too much time. The final list of intriguing manufacturing processes include:

- Deep drawing
- Electromagnetic forming
- Micro-blanking
- Press-forming / blanking
- Roll forming
- Spinning (under specific circumstances)

Besides these particular sheet metal production techniques. In addition to welding, shrinking, and stretching, it is also possible to cut metal. Another alternative is laser cutting.

Appendix H: Additional information legislation

In this appendix the most important requirements from each legislation will be listed, along with more explanation per regulation.

Food labelling regulations:

Regulation (EU) No 1169/2011 on providing food information to consumers [71]

Mandatory information:

- Food's name
- List of ingredients
- Net quantity
- Use-by-date
- Instructions for use, if necessary
- Operator's name and address
- Nutrition declaration

More rules are

- The information no the packaging must not mislead consumers.
- General rules about country of origin, which is mandatory when it might mislead consumers in thinking the origin of the food is different from place of provenance

Regulation (EU) No 2018/775 on providing indications of country of origin of primary ingredient [72]

This regulation is specifically about referencing country of origin of the primary ingredient. This does not only include a general rule compared to the previous regulation.

Materials in contact with food

Regulation (EC) No 1935/2004 general safety principles of food contact materials [73]

General principles:

- Materials do not release their their constituents into food at levels harmful to human health
- Materials do not change food composition, taste and odour in an unacceptable way

Requirements:

- Materials and articles, including active and intelligent materials and articles, shall be manufacturer in compliance with good manufacturing practice so that, under normal or foreseeable conditions of use, they do not transfer their constituent to food in quantities that could endanger human health, bring about unacceptable changes in compositions of food or bring about a deterioration in the organoleptic characteristics thereof.
- Labelling, advertising and presentation of a material or article shall not mislead the consumer

Sustainability

Directive (EU) 94/62/EC about management of packaging waste [74]

It is about management of waste, including the prevention of waste. This directive has established rates of recycling to be met.

Essential requirements are:
1. Manufacture and composition of packaging:

- The packaging is manufactured in such a way that the volume and weight are as low as possible, while complying with functional requirements in terms of safety, hygiene and acceptability of the packaged product;
- The packaging is suitable for re-use, recycling or recovery, with minimal environmental impact.
- The packaging is suitable for incineration or landfill and thus contains no harmful substances.

2. In respect of re-use of packaging, the following criteria must also be met:
- The characteristics of the packaging make it suitable for re-use;
- The packaging can be produced in compliance with labour regulations;
- If the packaging is no longer being used and has thus become waste, it must comply with the criteria for recovery.

3. Recovery of packaging material:
- A certain percentage of the weight of the used packaging material can be used again, or;
- The packaging must generate energy when incinerated, or;
- The packaging can be composted in a way that does not hinder composting activity.
- Biodegradable packaging waste must be physically, chemically, thermally or biologically degradable to the extent that the largest component of the resulting compost ultimately disintegrates into carbon dioxide, biomass and water.

Directive (EU) 2008/98/EC reducing waste an impact of resource use [70]

This directive drives to decrease the amount of waste by improving the usage of material. Example of measures taken are:
- Deposit schemes
- Economic incentives
- Minimum reusable packaging rate for each packaging type.

This directive also states that by 2025, a form of producer responsibility has to be in place for all packaging types in all EU member states.

Directive (EU) 2018/852 is an supplement to directive (EU) 94/62/EC [74]

This directive was intended to contribute to the transition to the circular economy; preventing packaging waste, stimulating the reuse of packaging materials and recycling packing materials instead of eliminating them from the chain entirely.

Regulation (EU) 2022/0396 [80]

This regulation is the continuation of directive (EU) 94/62/EC. The difference is in the fact that this is a regulation and not a directive. Which obliges all member states to uphold to these requirements once the regulation is of effect. This regulation has several requirements for reusable packaging.

Regulations, for reusable packaging that it should be designed so that,
- It can be emptied or unloaded without damage to the packaging, which prevents reuse
- It is capable of being emptied, unloaded, refilled or reloaded while ensuring compliance with the applicable safety and hygiene requirements
- It has been conceived, designed and placed on the market with the objective to be re-used or refilled
- It is capable of being reconditioned in accordance with annex VI, whilst maintaining its ability to perform its intended function
- It can be emptied, unloaded, refilled or reloaded while maintaining the quality and safety of the packaged product and allowing for the attachment of labelling, and the provision of information on the properties of that product and on the packaging itself, including any relevant instructions and information for ensuring safety, adequate use, traceability and shelf-life of the product
- It can be emptied, unloaded, refilled or reloaded without the risk to the health and safety of those responsible for doing so
- It has been conceived and designed to accomplish as many trips or rotations as possible in normally predictable conditions of use
- It fulfils the requirements specific to recycling packaging when it becomes waste set out in article 6

Apart from the rules the packaging also needs to adhere to requirements of recycling, as the reusable packaging needs to be recyclable as well since it will end up there once it has finished its life cycle.

There requirements are:
- it is designed for recycling;
- it is effectively and efficiently separately collected in accordance with Article 43(1) and (2);
- it is sorted into defined waste streams without affecting the recyclability of other waste streams;
- it can be recycled so that the resulting secondary raw materials are of sufficient quality to substitute the primary raw materials;
- it can be recycled at scale.

Manufacturing of packaging

Regulation (EC) No 2023/2006 about good manufacturing practices for materials and articles intended to come into contact with food [76]

Rules:
- Printing inks need to be formulated and/or applied in such a way that the substances from the printed surface do not transfer to the food-contact side
- Printed materials and articles shall be handled and stored in their finished and semi-finished states in such matter that substances from the printed surface are not transferred to the food-contact side.
- The printed surface shall not come into direct contact with food

Appendix I: Interview/meeting Loop

The interview/meeting took place on January 13th. This is following the signing of the NDA with Tata Steel.

The first part of the meeting was summarised as follows:
Dents in dry food products are usually less severe. The brand owner establishes the standards and decides which ones are acceptable.

They separate between dented and undented, and the final check is with the brand owner.

The profit margin for a long-term plan appears to be about right at the moment, even though they are not making any money.

In the future, the cleaning and logistics costs appear to be reasonable. However, it is currently much higher. The most expensive costs are those for storing empty packaging. They must keep this in storage when not in use.

They use a batch system, so they clean each type of packaging at the same time. This means that it may take some time for one type to be cleaned and thus require storage; additionally, it may take longer for packaging to return.

The packaging dimensions are important because certain dimensions do not fit into their system. She will send a document containing information about the requirements as well. She claims that longer packaging is more profitable than shorter and wider packaging.

Then questions:
Did you do any research to determine which reuse system to use?
Initially, the company operated as an e-commerce platform, delivering reusable packaging and returning it to your doorstep.

It is currently refilling the packaging and bringing it back to the store. They want it to look like single-use packaging. You should have the impression that you can throw away the packaging. The only difference is that you must return the packaging for a deposit.

The reason for this is unknown, but she believes it was more profitable for the business.

Which requirements do you have for the reusable packaging?
She has several requirements, including material requirements, design requirements, and compatibility with our cleaning system.

We now have three types of materials in the loop: stainless steel (some aluminium), glass, and plastic. Glass is a widely used material. Many businesses already have their products in glass and do not need to change the packaging for reuse. They are being tested, and if everything checks out, we will simply use the packaging that they already have.

There are three rules for reusable packaging: is it long-lasting? There are three types of packaging: plug and play (when good packaging already exists), portfolio packaging/stock packed (one they already own for another brand) and speciality packaging (packaging designed specifically for that brand).

The material must pass the internal testing standard, which is very high. It must meet our cleaning standards. Which is also high due to the temperatures and chemicals we use.

She can send a document with an overview of the loop and some details about the requirements.

Do you separate the different types of reusable packaging during washing or does this happen afterwards or before?
- Is this an automated or manual process?

We currently use a batch system. We have set aside time slots for each packaging. This is due to the various requirements that some packaging may have. When allergens are used, they must be cleaned separately.

In a more upscale version, they might be able to do one type of packaging at a time. Perhaps all cups of BK and McD. Various brands together.

The separation procedure is both manual and automated. Soaking the packaging is a laborious task. It all goes into the washing machine, which is manually loaded, and then into the drying machine.

We also collaborate with third-party washing companies that are more automated. The system described is the system that they have used for the last two years. However, they are in the process of changing, so much will change on their end as well.

We can conduct some washing test testing for you in the United States. The durability test can be performed in the United Kingdom.

Do you trace your current packaging?
We did not have a large enough stock in the UK or France to require it to track how many cycles. Some brands have addressed this issue. So they can keep a close eye on the packaging quality as well.

To track the packaging cycle, we are considering using RFID tags or another type of technology. Perhaps a barcode would prevent this.

Do you have your own logistics to collect the packaging from the stores? Or do you hire another company for that?
We have our own in some places, and we hire our own people. DHL was taking care of that for us in the UK. Our washing facility was located within the DHL facility. They were very close to being collected.

The packaging is returned in a bag, but it is also returned without a bag, and it is 'thrown' in a bag. During this process, the packaging may collide with one another and be damaged as a result. It has even happened that their glass packaging has broken during this process, with between 2% and 3% of the glass breaking.

They attempted to design the tote bag with a Cushing inside so that they would be less damaged.

Stacking the packaging would be ideal for transporting between cleaning and brand owner. LCA stacking could have a significant impact.

How often do reusable packaging fall during one cycle? (assumption)
It's difficult to tell from the consumer's perspective. We try not to let the packaging get in the way of their handling. We throw away the packaging when it falls from a certain height.

We will discard the packaging if the dent is too large. The brand owner has set this acceptance. At the moment, the decision is made manually. However, they are working on a camera system to inspect the damages and separate the ones that are no longer usable.

How does your cleaning process work?
It consists of three stages. Soaking, washing, and drying. We take samples at the end of the drying process and test them for allergens and bacteria. Will confirm with the quality what specific testing they perform.

We use surfactants for soaking, and the temperature is between 60 and 70 degrees Celsius. It is usually sufficient to remove the label, and product residue will be removed as well. The soak time is determined by the products. There is a great deal of variation depending on the product and label. Labels are not always intended to be removed. Try to concentrate on labels as well; this is a major issue right now. Some labels require two or three soaks to be removed from the material. Because of the surface, this is also dependent on the type of material. The standard soak cycle time is between 10 and 20 minutes.

Some materials with permanent decorations are not soaked off, so we do not always remove the labels. We have to remove the labels a lot of the time.

We use sodium hydroxide washing detergents for the wash, and an acid-based solution for the rinse. The washing cycle can last anywhere from 15-20 to 30 minutes. It takes the same amount of time to dry.

Certain materials, such as aluminium, must also be avoided because they react with sodium. We have various settings for various products. It is determined by the material used.

They test the bacteria after they have dried. ATB testing involves swapping the cans to determine whether any bacteria remain.

How do you dry your packaging?
The drying system is based on a conveyer system. It is placed on a rack and then on a conveyor. It's called a drying oven. In particular, dry utensils.

Temperature range. It is not higher than 80 degrees for plastics and PP. It can reach 90 degrees for metals and glass. If a product is not completely dry, the process will be repeated.

Where do the foul/defect packaging get separated?
After washing, we inspect for any damage or cracks. That is done by the quality control person. It is their responsibility once it reaches the brand. They are currently being manually checked.

When they are no longer needed, they are recycled. It is unknown what happens to steel packaging, but it is usually recycled.

Appendix J: SWOT-analysis stakeholders

Using the information gathered from use and user research and market research, multiple SWOT analyses were conducted for the stakeholders. According to the stakeholder mapping produced in the market research section, the stakeholders for whom the SWOT analysis was conducted must be monitored or satisfied. The SWOT analysis will reveal these stakeholders' strengths and opportunities, as well as their threats and weaknesses. Using this information, it is possible to develop a business plan that will be beneficial for all ecosystem stakeholders.

Metal manufacturer

In this case, the metal producer, Tata Steel, will be the first stakeholder to be examined. This is because implementing a reuse programme would likely reduce the quantity of material sold. To ensure that they will continue to profit from promoting the reuse system, a strategy is required.

Internal strengths & weaknesses
Tata Steel's strengths include the production of high-quality steel as well as Protact®. Tata Steel also has positive relationships with can manufacturers and brand owners. The ability to evaluate new designs in their factories prior to implementing them across an entire can production line allows manufacturers to save time and money while determining whether they will be successful. Tata Steel's expertise in the production of cans enables them to evaluate these designs.

Currently, a limited quantity of Protact® is manufactured. Every other week, they alternate between using the coating line and fusing the coating to the metal. Tata Steel is not in close contact with consumers; as a result, they are unable to respond effectively to market demand and do not know precisely what consumers want (until a brand owner takes action).

External opportunities & threats
If Protact® is utilised more frequently, Tata Steel may raise the material's price and still generate a profit. Innovative would be leasing the material and then leasing the cans from the manufacturer of the cans. Tata Steel retains ownership of the material, while the can manufacturer and brand owners pay less per use cycle to utilise it. When the product's lifespan expires, the cans and materials are returned to Tata Steel, where they are pressed into new steel sheets and sold at a discount (assuming the packaging can withstand many reuse cycles).

Tata Steel's inability to switch to a carbon-neutral alternative as quickly as its competitors could pose a threat. As previously stated, reusable packaging has decreased the demand for new materials, posing a challenge for

Can manufacturer

The manufacturer of cans is the subsequent stakeholder to be evaluated. This stakeholder will also generate fewer cans due to the longevity of the repurposed cans. A strategy must be developed to maintain their interest. If can manufacturers refuse to cooperate, the introduction of reusable packaging will be difficult. It may be necessary for brand owners to establish their own can manufacturing facilities.

Internal strengths & weaknesses
The ability to produce a wide variety of high-quality cans is one of the strengths of can manufacturers. This also occurs rapidly, allowing them to produce a large quantity of cans in a short amount of time. Depending on the can manufacturer, the level of design innovation may be high. In addition, they facilitate the shipment of cans between themselves and brand owners. The relationship they have with brand owners is another benefit. They can collaborate with firms like Tata Steel to develop designs that meet the requirements of brand owners. In addition, they produce packaging for numerous industries, including food, aerosol, and universal line.

Design enhancements may be time-consuming and costly to implement. Therefore, before implementing the adjustment, they must be certain of its success. They also lack direct consumer contact, which is another disadvantage. They obtain the information from the brand owner, who serves as a middleman in this circumstance. Some can manufacturers have already invested in their own coating process, in which case it will be much more difficult for them to employ Protact® because they no longer require the coating line. There are numerous competitors who manufacture cans, and in some cases brand owners are expanding their own can manufacturing line.

External opportunities & threats
The can manufacturer could lease the cans and generate revenue per cycle or month. Guaranteeing that they will still generate a profit even if demand for new cans decreases. Another option would be to charge a higher price for the cans, as they would also be more durable. In order to expand their portfolio and enter new markets for the sale of their packaging, they may seek out new markets for the deployment of reuse packaging. Providing options for packaging repair is yet another possibility for can manufacturers. Ability to remove dents from packaging that was destined for the trash but could still be used.

If cans are reused multiple times, the can manufacturer will sell fewer cans, posing a threat to their business. If they don't produce reusable cans, they will lose business to competitors who do. The fact that they do not utilise their coating line, should they have purchased their own coating line, poses an additional threat to can manufacturers utilising Protact® packaging. Moreover, this would lead to investment losses.

Raw material provider

The raw material supplier is another stakeholder whose participation will be evaluated. They would suffer the most if a system of reuse were implemented. Due to the fact that they would be excluded from both the reuse and recycling systems. This analysis was conducted to determine what steps could be taken to mitigate the damage to their business.

Internal strengths & weaknesses
The ability to collect and distribute raw materials globally is an asset of raw material suppliers. They are in contact with metal producers. They could own the equipment used to extract the resource, which would be advantageous. In regions where raw materials are extracted, where labour costs are low, raw material prices are also kept low.

Equipment failures represent a weakness for the raw materials supplier. The essential minerals that are being extracted are finite and will eventually run out. Changing locations could be beneficial, but they will soon need to seek out new resources. It will take time to transport the equipment between different locations.

External opportunities & threats
Finding new materials to excavate presents opportunities for the raw materials supplier. Since recycling packaging and materials will significantly reduce the amount of needed resources, this practise is encouraged. Up until a certain point, the price of raw materials may be increased. If they raise it too much, they risk losing business to a competitor who does not raise prices and has a backup plan. The raw material supplier may still sell to metal producers who discourage reuse. Another opportunity for the supplier of raw materials would be to use the equipment they already own to collect plastics from nature and sell them to companies seeking recycled plastics, as these plastics are also becoming more valuable.

As previously mentioned, one of the threats to the suppliers of raw materials is the possibility that additional material may not be required in the future, in which case the materials being unearthed would be worthless. Lastly, poor working conditions may be present during the extraction of the raw material. Someone will then become aware of it and cease purchasing the material from that supplier.

End-of-life provider

The provider of end-of-life will be the subject of the final analysis. This stakeholder is at the end of the system's lifecycle, as depicted in the ecosystem section. Reduced likelihood of materials ending up in recycling facilities due to increased reuse. The SWOT analysis was conducted to ensure that they have a backup strategy.

Internal strengths & weaknesses
A strength of the end-of-life provider is its ability to differentiate between different types of materials. They can separate materials like plastic, metal, and cardboard. The material can be landfilled, incinerated, or recycled. This is determined by the value of the material. Additionally, they have the infrastructure to collect and sort materials from a wide area.

Their inability to process all substances is one of their weaknesses. Some materials, such as multilayer bags and black plastic, are challenging to recycle and therefore end up in landfills. Another weakness is that most of the materials discarded by end-of-life providers end up in landfills.

External opportunities & threats
Following a decrease in labour due to reuse, the provider of end-of-life services has multiple opportunities to increase labour. Using their current technologies for separating material categories, they could aid in the separation of reusable packaging. Given that they already possess the equipment. Another option is to incorporate the collection of reusable packaging into their garbage collection service (becoming the refill/return provider). Finally, they were able to invest in machinery that could recycle previously unrecyclable materials. Providing them with more valuable materials that could be sold.

Inactivity poses the greatest threat to those who provide end-of-life. As they have numerous opportunities, doing so would result in less business for them. By employing any of these strategies, they will increase their business.

These analyses illustrate the variety of options that can be considered when composing a business plan. There are several options available, the selection of which depends on the selected reuse system. Therefore, in addition to consumer preferences, this should also be taken into account.

Appendix K: Additional information patent research

This research was conducted to determine what types of reusable packaging patents are available on the market. This may provide valuable insights into the current market, such as what will be sold and which techniques are no longer applicable.

During the research process, terms such as reusable, packaging, and metal are sought. This has led to several interesting results for this research. The most important finding of this research is that there are currently no patents covering reusable metal packaging or specific characteristics that may be of interest for such packaging. In the following section, several patents of interest are presented and discussed.

The first patent to be discussed concerns a reusable candle container (US2022316695A1) [96]. This is a patent for a container that includes a refill. The patent describes the various components of the invention. This is intriguing because using refill for the project could also be an option.

The second patent (CN216154464U) relates to cap replacements [97]. This patent is intriguing because it demonstrates the possibility of replacing a packaging component while maintaining the packaging's functionality. Which is another packaging design option that could be considered.

The third patent (CN2023746101U0) relates to a reusable RFID tag [98]. This patent demonstrates that RFID tags can be reused. Therefore, it may be possible to reuse an RFID tag after the metal packaging has been discarded, thereby enhancing this aspect of reuse. In this instance, RFID tags are applied to the packaging.

The fourth patent (WO2021001843A1) covers reusable pallet warp. This intervention can be utilised to create secondary packaging from reusable packaging. During the lifetime of reusable packaging, no single-use plastic should be wasted.

The fifth patent (JPS57163649A) relates to display packaging [100]. Even if the metal packaging is not transparent, it could be interesting to demonstrate the interior of the packaging. In this situation, such a product could be utilised.

The last patent to be discussed relates to a reusable tea packaging (CN204078263U) [101]. This patent demonstrates that reusable tea packaging already exists, which was also considered as a food option. In the case of tea packaging, some of the insights from this patent may be incorporated into the design of the reusable packaging.

These patents demonstrate that there are numerous options available for reusing packaging. This research has aided in looking beyond the packaging industry for potential solutions and being open to out-of-the-box ideas. Importantly, it is now known that there are no existing patents for the reusable packaging that will soon be introduced.

Appendix L: Material research analysis life cycle reusable packaging

In this appendix, each step required to complete one reuse cycle will be detailed. From food insertion to return of empty packaging, they are divided into four sections, as these four steps comprise the reuse cycle. Figure 16 illustrates the reuse cycle.

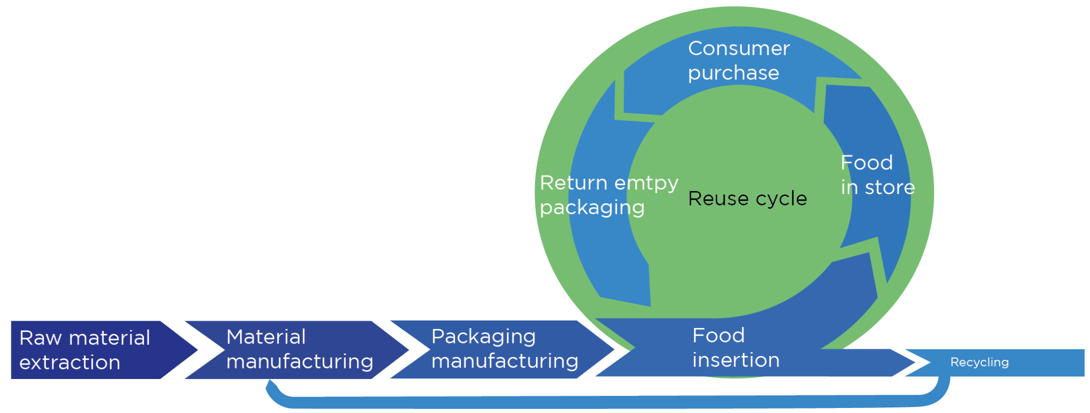


Figure 16: Reuse cycle

The following lists detail the steps required to fill the packaging up until it is returned. Red indicates the steps that are determined to be the most detrimental to the packaging. In addition to these processes, transportation causes packaging damage, which will also be considered; these steps are not highlighted in red because they occur at various stages of the reuse cycle.

Food insertion

- Packaging removal from the box in which they were shipped.
- Placement on conveyor belt.
- Insertion of food.
- Closing packaging.
- Placement inside of secondary box, and tertiary pallet.
- Pellet placement inside of truck.
- Transportation for X minutes, from producer to retailer.

Food in store

- Removal pellet from truck.
- Placement secondary box on trolley.
- Placement primary packaging on shelf.
- Product reviewed by consumer (before purchase).
- Placement primary packaging in supermarket cart.
- Purchase of product.

Consumer purchase

- Transportation primary packaging, from retailer to consumer home.
    - o With bike, on steering wheel.
    - o With car.
- Placement primary packaging inside home.
- Storing primary packaging.
- Opening primary packaging, with knife or can opener for example.
- Usage of primary packaging.
    - o Using a spoon or knife to empty the contents.
- Transportation primary packaging inside home.
- Transportation primary packaging, from consumer home to retailer.

Returned empty packaging
- Placement packaging in vending machine.
- Transportation empty primary packaging, from retailer to cleaning facility.
- Cleaning primary packaging.
- Placement clean packaging into secondary boxes.
- Transportation primary packaging, from cleaning facility to brand owner.

Appendix M: General setup material research (packaging used)

This section provides an overview of the material testing procedures, including the packaging and specific materials employed. The generic test cans used in the tests are manufactured by Tata Steel and have a diameter of 65mm and a height of 93mm (approximately 2+11/16 inches in diameter and 3+11/16 inches in height), using DRD manufacturing techniques. The creation process consisted of the four steps depicted in figure 17.

Figure 17: Steps creating test cans

Thin substrate number SH-2022-0593 (0.17mm) and thick substrate number SH-2022-0744 (0.22mm) were utilised during the droptests. The Protact® cans used for these tests were only coated on both sides with PET, as the difference in substrate thickness was crucial to the research but not the coating type. Unfortunately, Protact® with PET and PP was not available at the time of the study, but it would have been utilised if it had been.

Protact® sheets with PET and PP (PET on one side and PP on the other) were used to observe the difference between the two coatings during handling tests and microscopic research. These sheets are placed within Appendix P. The sheet samples used have the number SH-2021-0346 in the Tata Steel database.

As Tata Steel was unable to produce a Protact® packaging with a screw thread, a different packaging was utilised for the closure test. Figure 18 depicts two Protact® cans with screw threads supplied by Zaanlandia for the project. Unknown is the type of Protact® used for these cans, but the coating is PET.

Figure 18: Protact® packaging with screw thread

Appendix N: Microscopic research

This section will explain the microscopic research. There were five types of microscopic techniques used for this study. These include the light optical microscope (LOM), Fourier-transform infrared (FT-IR), differential scanning calorimetry (DSC), energy-dispersive X-ray (EDX), and Raman spectroscopy. These will be explained in more detail later in this appendix.

Microscopic research was conducted to determine the limitations of the materials. PET and PP are the materials that are compared in this study. This research's findings were utilised as background information for the other material research conducted.

Goal:
The aim of this research is to determine the melting temperature, water absorption and washing solutions absorption limits of Protact® PET and PP.

Research question:

- What is the melting temperature of PP and PET Protact®?
- How does PP and PET react to water?
- How do PP and PET Protact® respond to specific washing solutions?

Materials used:
The samples described in the general setup material research were utilised for this test. They were reduced in size to 40 mm by 40 mm. For the Raman, they had to be cut even smaller, as the heating camber did not permit sizes larger than 4 mm by 4 mm.

Setup:
For these tests, the null measurements will be taken using a sheet that has not been affected (also known as a "blanko"). This sample will be used to compare the samples that have undergone testing.

As previously stated, these tests will be conducted using PP and PET. As the information from both sources is essential to possess.

Before performing tests, the samples were examined with the optical microscope. This will demonstrate the appearance of the unaffected material. This will be performed at least once per sample, using Protact® PP and Protact® PET in this instance.

Figure 19 depicts the Raman, which also contains the heating chamber on the right.

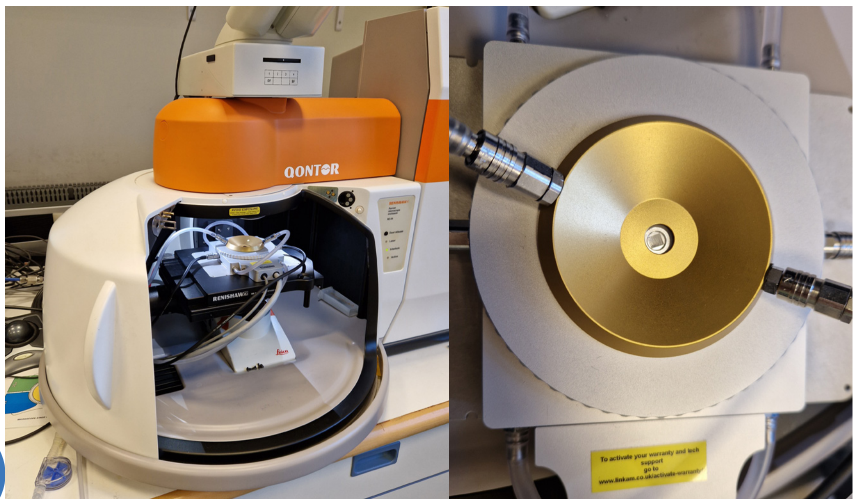


Figure 19: Setup confocal Raman spectroscopy (temperature cell on the right)

Tests performed (+ results):
Test 1 – What material am I working with?
As previously stated in the main report, prior to conducting any heating tests, it is essential to know with certainty the type of material being tested. For this examination, the FT-IR and the Raman were utilised. They will show the material type, and using Raman, it is possible to estimate the material's thickness. The results of the two techniques will be presented in the subsequent section.

The utilised FT-IR is a Tensor II (Bruker) equipped with an ATR-Diamond. The settings for the scans are 32 scans at a resolution of 4 cm-1.

Renishaw's Qontor Raman spectroscopy is used, and its default settings are green laser (532 nm), grating 1200 (extended), laser power 10%, exposure time 1 second, accumulation 1x, and a 50L objective. When adjustments are made to these settings, they will be listed in the results.

FT-IR
This technique uses infrared to determine the material composition of a sample. This is accomplished by sending radiation to the sample and measuring the vibrations emitted by the molecules. Vibrations will manifest according to the type and strength of the bond. The only type of bond that can be measured using FT-IR is a dipolar moment bond. Thus, molecules consisting of different types of atoms, such as a C=O bond, are possible to be measured. Therefore, this technique is particularly useful for determining whether a material has absorbed water.

The FT-IR-measured vibrations will be plotted on a spectrum. The type of substance can be determined based on the peak's positioning. In figure 20, a sample spectrum is shown.

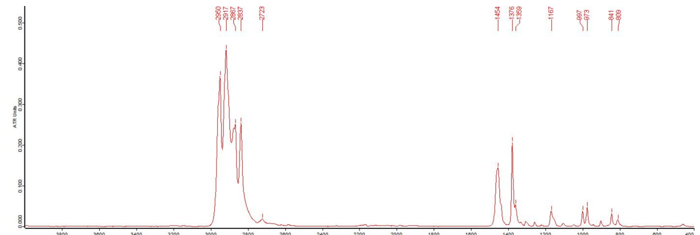


Figure 20: FT-IR spectrum PP

In this study, FT-IR was used to determine the type of material employed during the project. One side of the utilised sample was transparent, while the other side was white. Each side was evaluated.

It is shown that the transparent side that was evaluated is composed of polypropylene (PP). Figure 21 depicts the spectrum of the material, while Figure 22 depicts the comparison with the database. This comparison demonstrates that the material is PP.

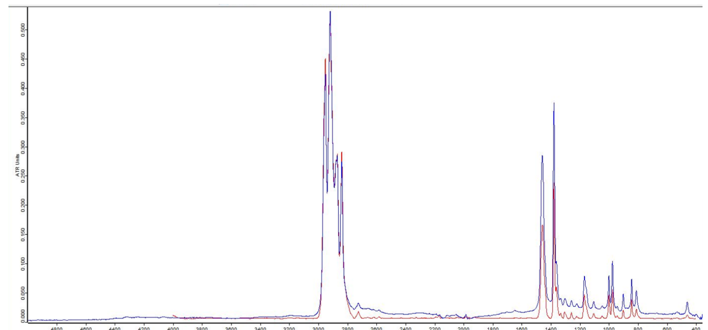


Figure 21: FT-IR spectrum Transparent side

Compound information	
Polymer	PP-H
CAS Registry Number	9003-07-0
Substance	polypropylene homopolymer
Trade Name	Moplen HP 400R
Supplier	LyondellBasell
Filler	unfilled
Filler Content	0

Figure 22: PP datatbase comparison

The opposite side (white side) was known to be composed of PET. However, it was unknown whether PET was amorphous or crystalline. The difference between amorphous and crystalline PET lies in the polymers' structures. Amorphous polymers are similar to cooked spaghetti, whereas (semi-) crystalline polymers are similar to both cooked and uncooked spaghetti combined. Due to its structured polymers, crystalline PET is known to be stronger. The FT-IR has revealed that the material is amorphous PET. Which is depicted in figure 23. Figure 24 depicts the comparison with the database. It must be noted that after deformation of the material the amorphous PET is likely to transition to crystalline PET due to the forces applied to it. The test were not performed with crystalline PET.

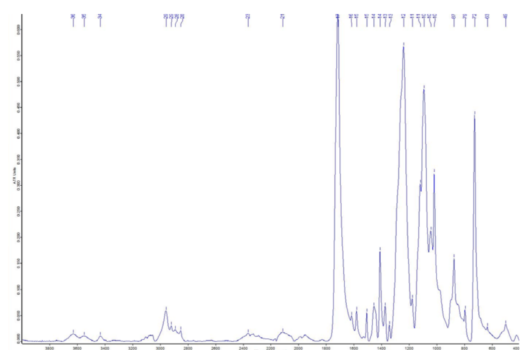


Figure 23: FT-IR spectrum white side

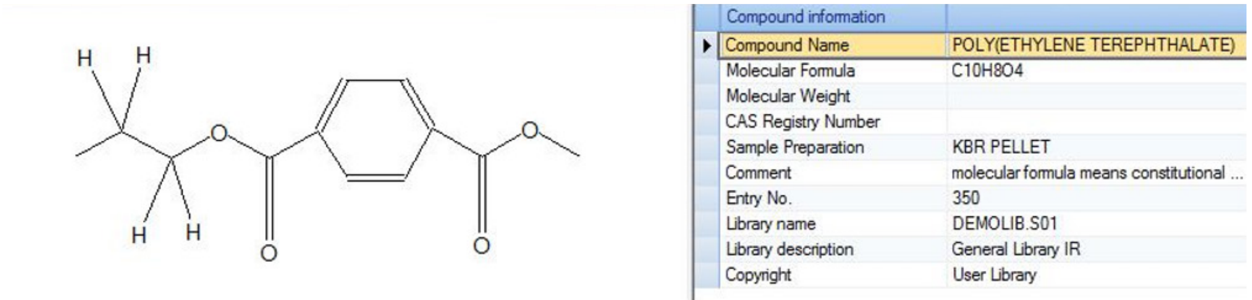


Figure 24: Comparison PET with database

Raman

Using a laser, this technique measures the vibration of the molecules. In contrast to FT-IR, bonds that do not have a dipolar moment, such as C=C bonds, are shown in Raman. This provides complementary information about a material in addition to the FT-IR results. This technique uses the same type of spectrum as the FT-IR.

The Raman utilised in the Tata Steel laboratory is also able to heat a small chamber. In addition, the Raman is capable of measuring the material's depth and its intersection with a surface. This allows one to see, for instance, if there are air bubbles between the coating and the substrate.

The transparent side was initially evaluated based on the type of material to determine if the FT-IR results were identical. This also demonstrated that the material is PP, so it is safe to assume that the transparent side is also PP. The Raman spectrum for the transparent side can be found in figure 25.

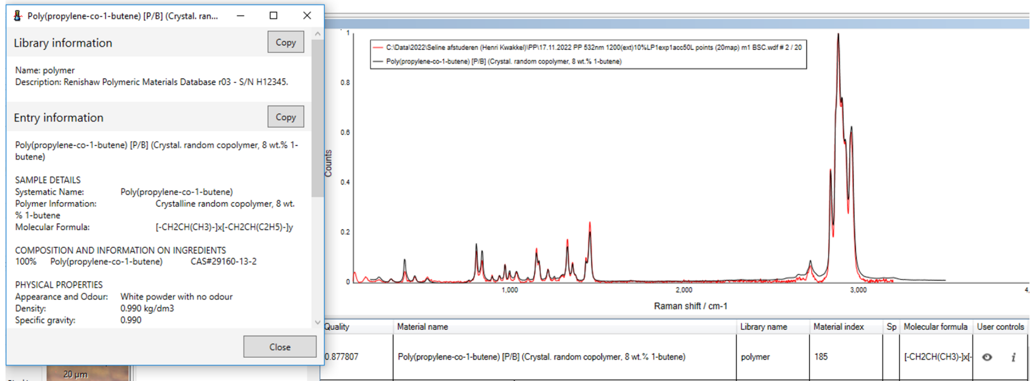


Figure 25: Raman spectrum transparent side

In addition, the Raman was utilised to determine the layer's thickness. In figure 26 the spectrum is shown. The thickness of the PP layer is approximately 40 Qm.

Using Raman, the white side has also been evaluated. This also indicated that the white side was composed of PET, confirming the FT-IR results. In figure 27, the spectrum is displayed.

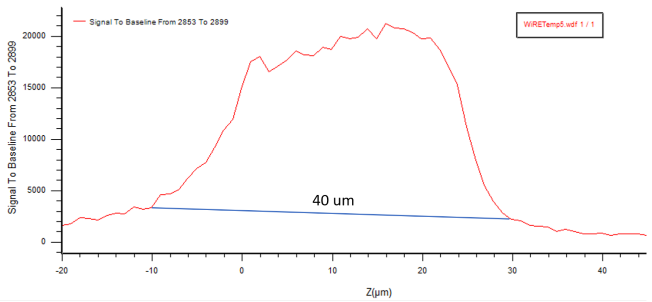


Figure 26: Thickness spectrum PP raman

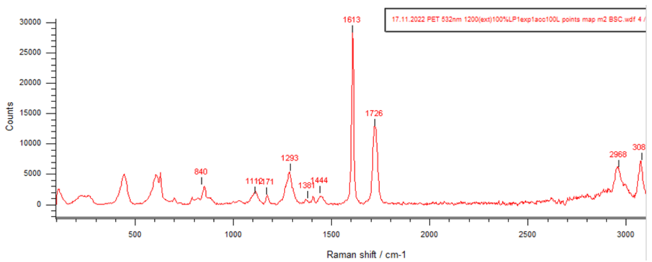


Figure 27: Raman spectrum white side

Raman has also been used to measure the thickness of the material's white side. In figure 28, the spectrum is shown. The thickness of the PET layer is approximately 25 Qm.

In addition to these tests, the Raman was used to generate a depth profile. Which has been carried out on the PP-facing side of the material. Figure 29 demonstrates the presence of air bubbles between the substrate and coating.

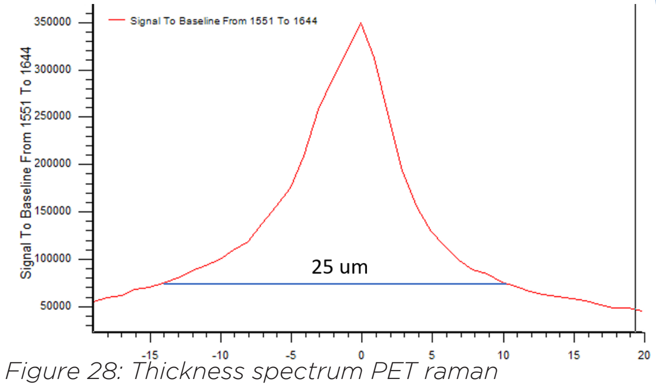


Figure 28: Thickness spectrum PET raman

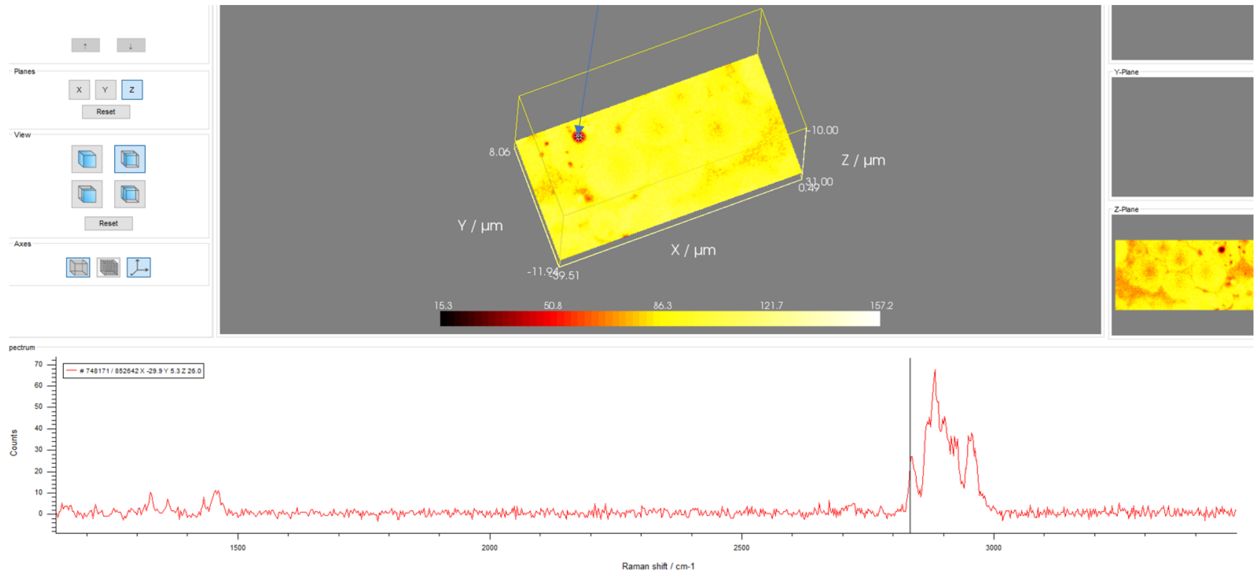


Figure 29: Depth measurement PP side

Test 2 – Finding melting temperature

This test was conducted using Raman and DSC. This decision was made due to the fact that PET and PP might react differently in nitrogen (DSC) compared to air (Raman).

As previously stated, the heating chamber of the Raman available at Tata Steel is capable of heating the material. Which allows the melting temperature of the materials to be determined. In addition to the melting temperatures, it is possible to determine when PET crystallises and when the glass transition occurs.

The settings for measuring the PET side of the material differ slightly from the previously listed general settings. The difference is the laser's strength, which is now 100% instead of 10%, and the accumulations, which are now 16x instead of once.

Prior to conducting the experiment, it was essential to have an idea of the melting point, crystalline transition, and glass transition. As this information was to be used to configure the Raman's heating chamber, it was essential. For PET, the melting temperature has been determined to be around 260 degrees, the glass transition temperature between 69 and 75 degrees, and the crystalline transition temperature around 130 degrees.

As previously stated, the atmosphere used in the Raman is air, which most closely resembles the natural environment for reusable packaging. Consequently, if the material is sensitive to air molecules, it may melt sooner. However, it is important to know this information because if only the DSC measurement is taken, this could cause a problem in the future. Since the maximum service temperature would then be excessively high.

Since it was anticipated that the material's melting point would be around 260 degrees, the Raman's heating chamber has been heated to 280 degrees. Figure 30 shows the melting point/trajectory. PET has a melting range between 210 and 260 degrees.

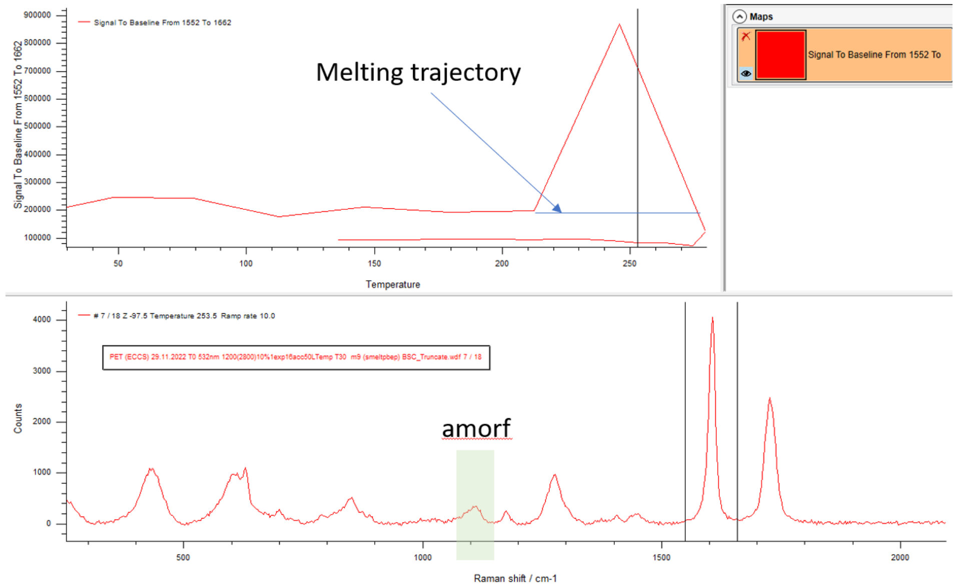


Figure 30: Raman melting trajectory PET

It has also been determined when the transition to crystalline PET occurs. As this may affect the material's properties, it is essential to understand. Using the same heating conditions, it was determined that PET crystallises above 110 degrees, as depicted in figure 31.

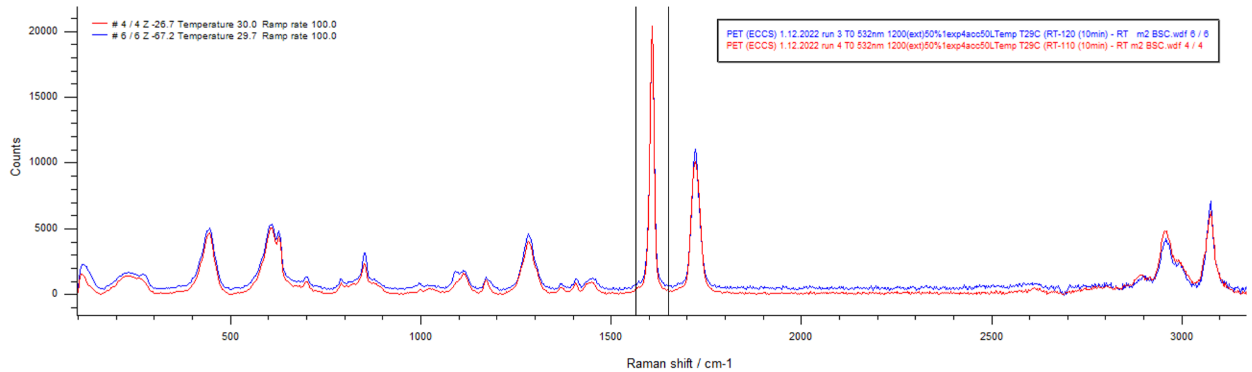


Figure 31: Transition to PET crystalline

The figure shows a distinction between peaks near the 1100 wavelength. Once these peaks combine into a single peak, the material will have transitioned into crystalline PET. However, conversations with colleagues have revealed that crystallisation can also occur at lower temperatures but after prolonged exposure to that temperature. In addition, PET typically crystallises after processing steps, as this creates a strain that causes the material to crystallise.

It was anticipated that PP would have a melting point of 160 degrees and a glass temperature of -10 degrees. For this test, the same conditions as PET were utilised. The heating chamber has been heated to 180 degrees using this data.

For the PP heating measurement, the Raman settings also change slightly. The only difference is that the scan accumulations are 16x instead of 1x.

This indicates that the melting point of PP is 160 degrees. In addition, it demonstrates that its composition does not change significantly during heating compared to PET. This is because, at room temperature, PP is already in glass state. The melting point of PP is depicted in figure 32.

According to research [A10] PP melts when the two peaks in the orange square combine into a single peak. This change occurs between 160 and 170 degrees Celsius.

Using DSC, the melting points and trajectories have also been determined. This technique also heats the material, but instead of measuring the material on a molecular level, the DSC measures the heat released, allowing for the determination of the material's state. The measurement was conducted with nitrogen as opposed to air. This can result in a different melting temperature for PET, but this was not anticipated for PP.

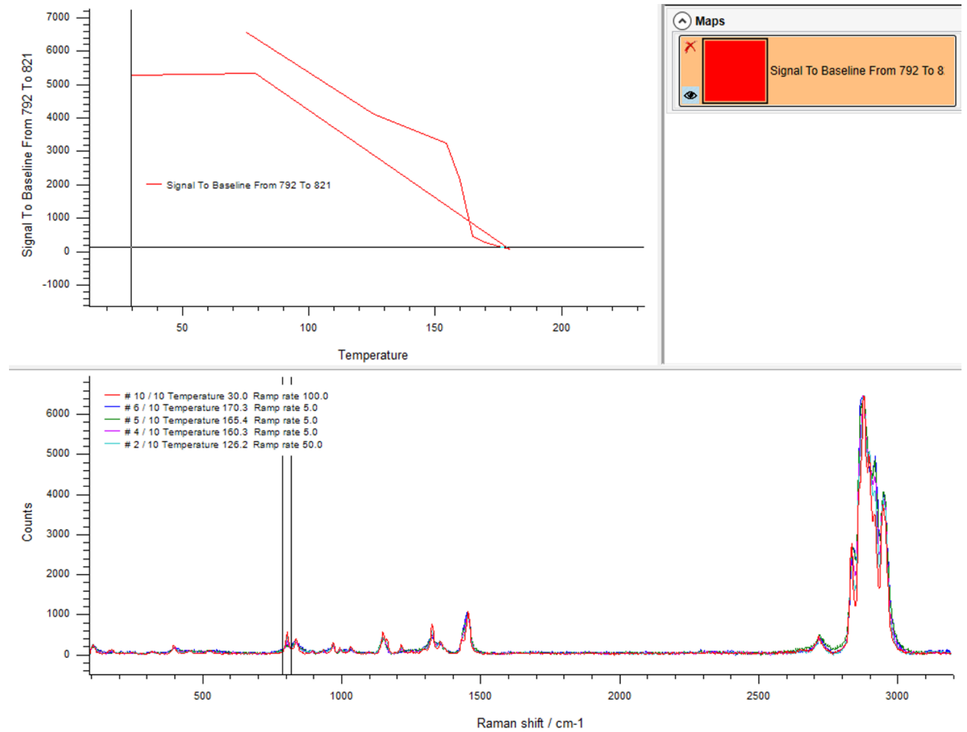


Figure 32: Raman melting point PP

The DSC spectrum of PET can be found in figure 33. The spectrum shows that the crystalline transition of PET occurs at a temperature of 127 degrees. The melting trajectory is between 220 and 250 degrees.

The spectrum for PP can be found in figure 34. The conditions were identical to the PET measurement. The spectrum shows that PP does not have a glass transition because its glass transition temperature is below 0 degrees, indicating that it is already in the glass state. The measured melting temperature is 165 degrees.

As anticipated, there is a small difference between the Raman PET and DSC PET measurement results. The difference between the melting point and its starting point is 10 degrees. This difference is not significant, but it should still be considered.

During the heating test, optical images were also captured. These were created to visually demonstrate what happens to materials when heated. Figures 35 to 36 contain images captured with an optical microscope.

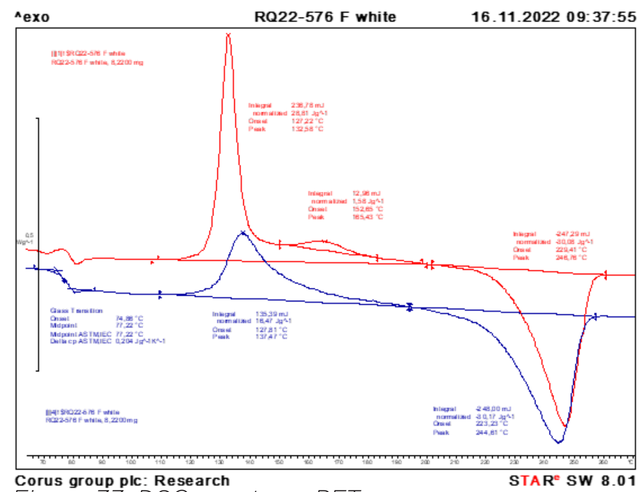


Figure 33: DSC spectrum PET

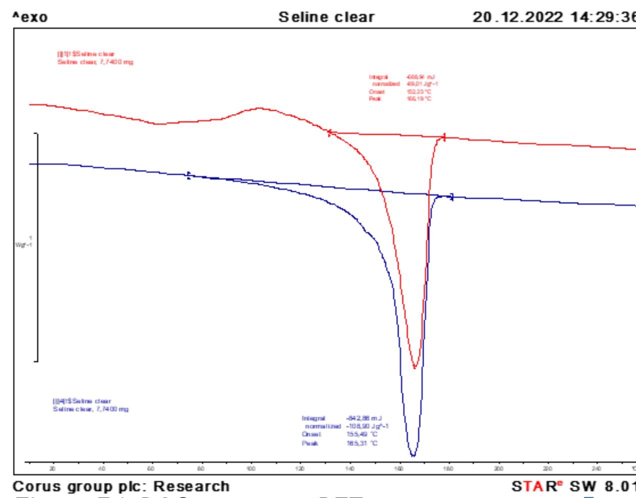


Figure 34: DSC spectrum PET

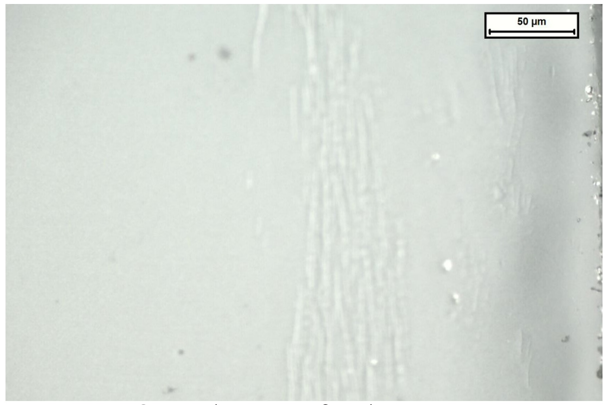


Figure 35: Optical image after heating up till 110 degrees PET (20x zoom)

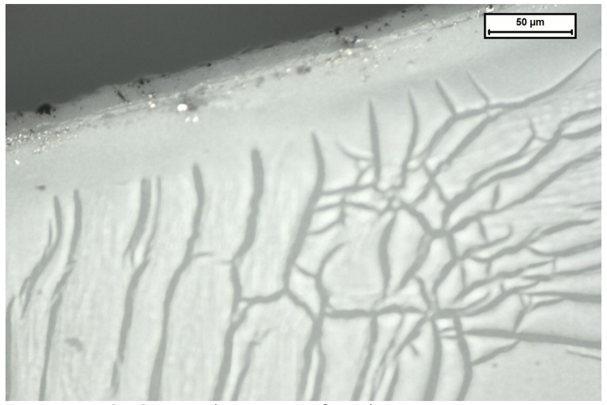


Figure 36: Optical image after heating up till 130 degrees PET (20x zoom)

The images demonstrate that at temperatures above 110 degrees PET is slowly releasing from the material's edges. This is due to the tension in the material, which releases once the material reaches the glass transition, causing the edges to release. The EDX was used to determine whether or not this was detrimental to the material. This technique measures the materials on a sample using atoms. As a result of the atoms that are created by the EDX, the sample is rendered unusable.

The sample's spectrum is displayed in figure 38. This indicates the material to be PET. All spectra generated for the 110-degree sample exhibit PET and lack any abnormalities. This demonstrates that the material's wrinkles are not "damaged" and cannot cause the substrate to rust. However, if the material's edges have release, it can be.

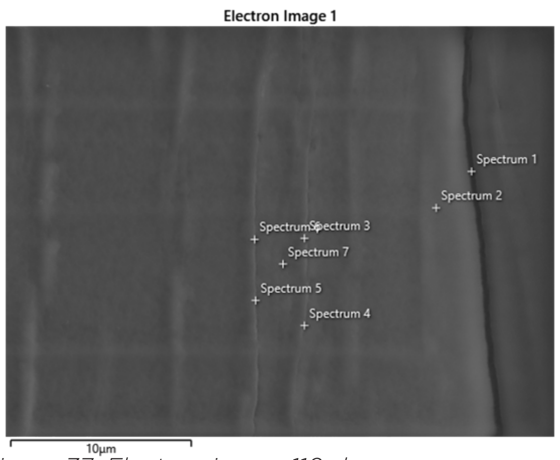


Figure 37: Electron image 110 degree

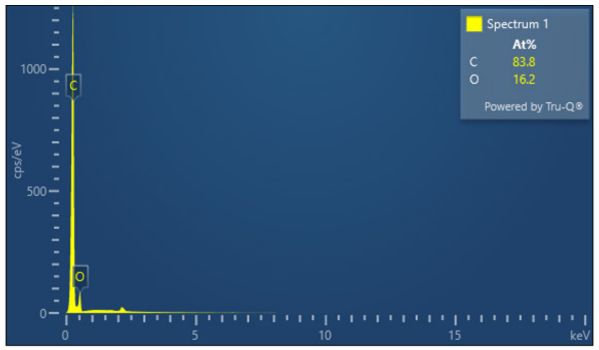


Figure 38: Spectrum 7 sample 110 degree

The electron image of a PET sample heated to 120 degrees Celsius is depicted in figure 39. In this image, wrinkles are also visible. Sample 2 (Figure 40) is intriguing in this measurement because it reveals a magnesium silicate fragment beneath the material. According to a discussion with a colleague, this is because these pieces allow the sheets of material to be stacked without sticking together. Aside from this, the material contains no holes or scratches that could cause the substrate to corrode.

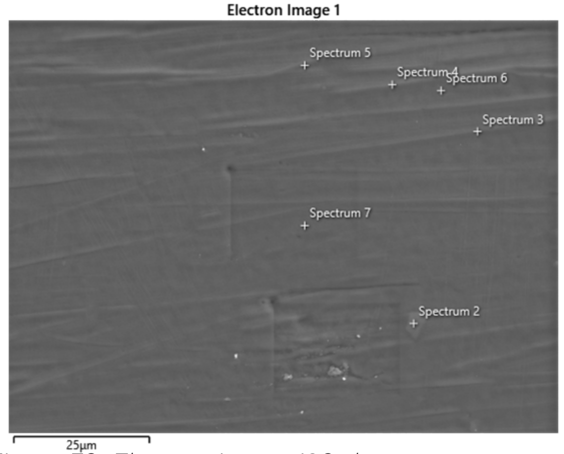


Figure 39: Electron image 120 degree

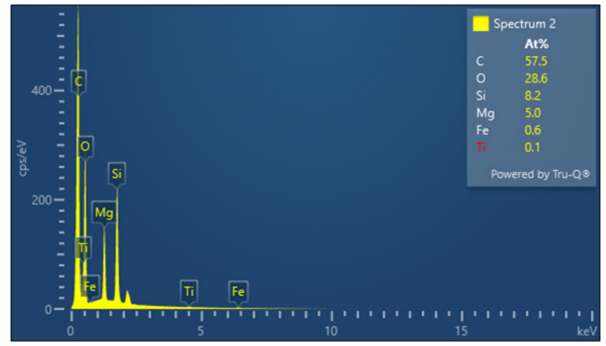


Figure 40: Spectrum 2 sample 120 degree

The electron image of a PET sample heated to 130 degrees is depicted in figure 41. The spectrum (figure 42) also reveals the presence of magnesium silicate beneath the material. Other than that, there is no way to comprehend the material. Except for the material release on the edges.

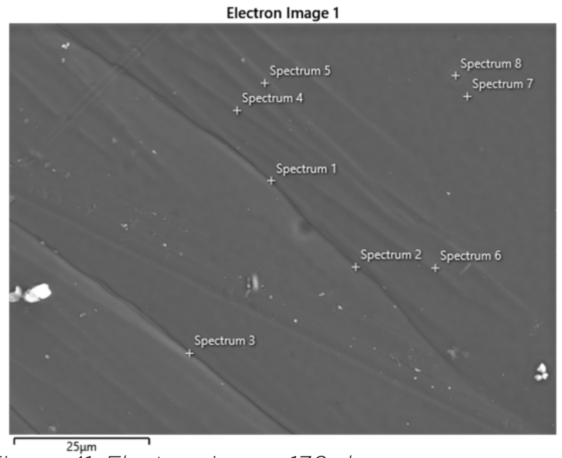


Figure 41: Electron image 130 degree

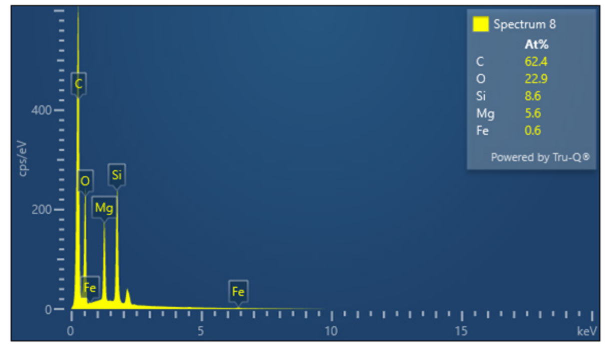


Figure 42: Spectrum 8 sample 130 degree

The electron image of a PET sample heated to 140 degrees Celsius is depicted in figure 43. The spectrum (figure 44) also reveals the presence of magnesium silicate beneath the material (in between the substrate and the coating). Other than that, there are no coating defects that would cause the substrate to corrode.

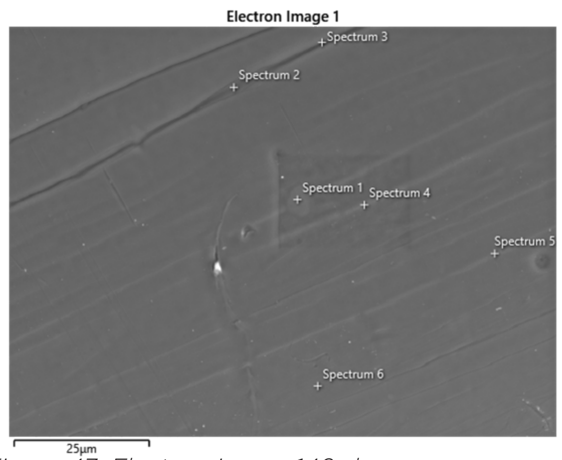


Figure 43: Electron image 140 degree

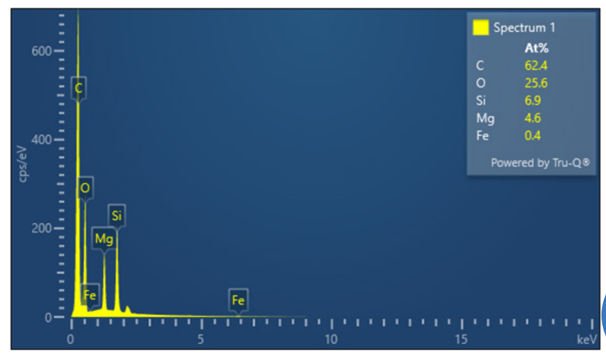


Figure 44: Spectrum 1 sample 140 degree

Test 3 – Coating water resistance (and washing solution)
This test has been conducted to determine how water affects the coatings. The samples were placed in a container with tap water and dishwater for three and twenty-four hours, respectively. The samples were then examined with the Raman and the optical microscope. The 3h samples have also been re-heated to determine whether the melting point has changed. Dutch tap water was utilised for this test.

The 3h PET water sample shows no difference in crystallisation temperature. Even when heated to 110 degrees, the material remains amorphous as can be seen in figure 45. It is essential to note that the sample was dried prior to heating.

The PP water sample that has been heated to 160 degrees for 3 hours reveals no difference, figure 46. Therefore, the 3h water had no effect on the melting points of the materials.

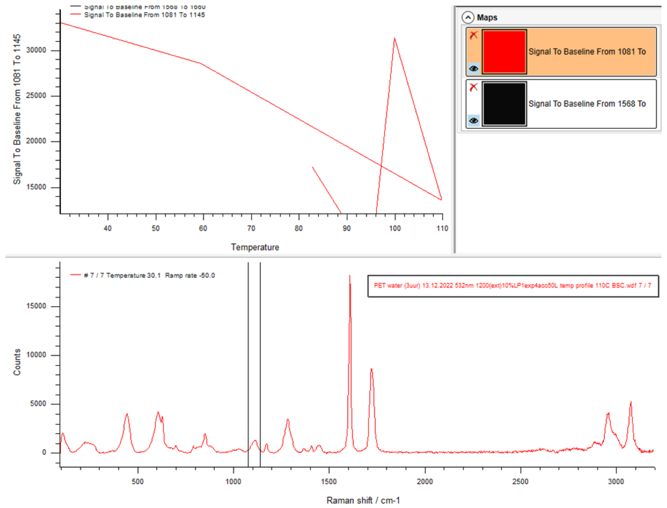


Figure 45: 3h water sample PET heated

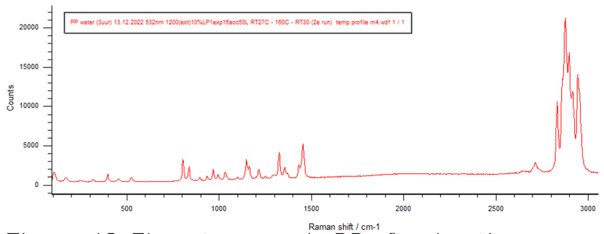


Figure 46: 3h water sample PP after heating

The optical images of the samples that were immersed in tap water for three hours are depicted in figures 47 through 50.

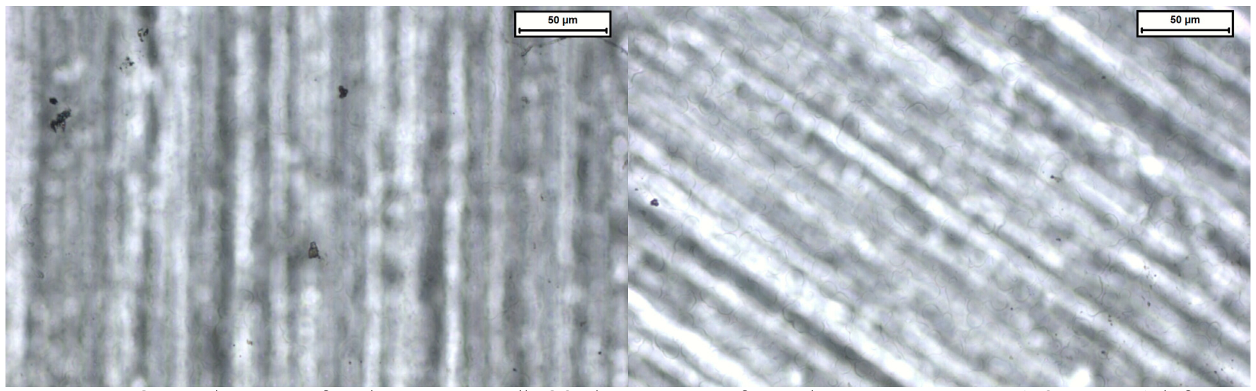


Figure 47: Optical image after heating up till 160 degrees PP after 3 hours in tapwater(20x zoom) left, optical image after heating up till 110 degrees PP after 3 hours in tapwater(20x zoom) right

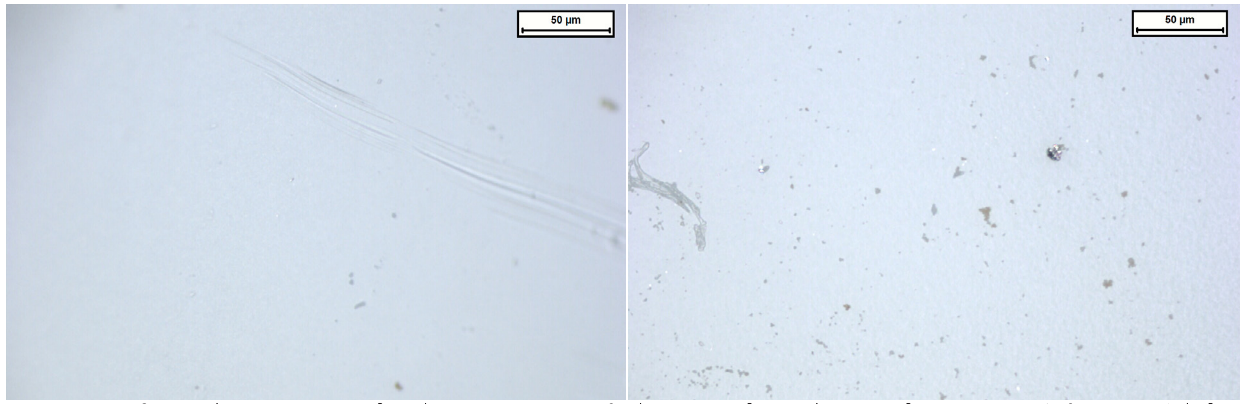


Figure 48: Optical image PET after heating up to 110 degrees after 3 hours of tap water (20x zoom) left, optical image PET after heating up to 160 degrees after 3 hours of tap water (20x zoom) right

In addition to soaking the samples in tap water for three hours, the test was repeated for twenty-four hours. In this instance, samples were placed in two separate containers, one containing tap water and the other containing dishwasher water (demi-water with soap). They were left inside for twenty-four hours. The optical images below depict the results after 24 hours.

After 24 hours of drying, optical images of the PET samples revealed that water droplets remained on the surface. With PP, the water was no longer visible. After 24 hours, there was no corrosion in the middle of the samples. Due to the nature of steel, corrosion was to be expected on the exposed edges.

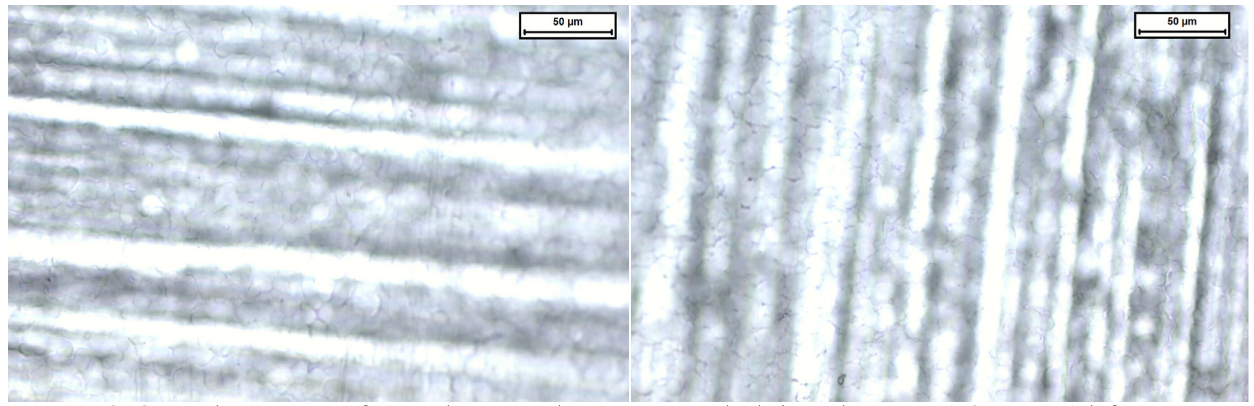


Figure 49: Optical image PP after 24 hours in demi-water with dishwasher soap(20x zoom) left, tap water right

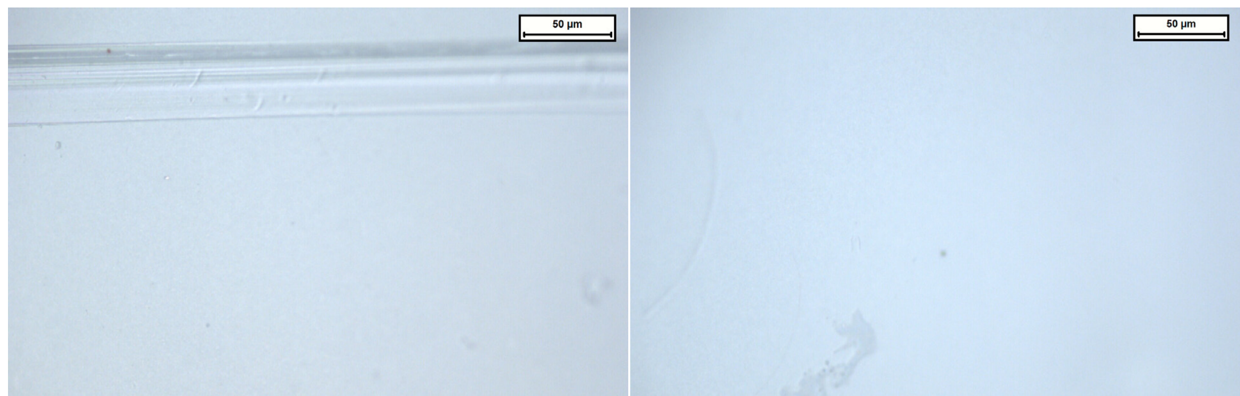


Figure 50: Optical image PET after 24 hours in demi-water with dishwasher soap(20x zoom) left, tap water right

Appendix O: Transportation

The material research for the transportation process will be explained in this appendix. The packaging must survive multiple drops during transport. It is essential that the packaging can withstand multiple drops before being discarded. Therefore, the tests will be conducted multiple times to determine the effect of multiple drops on the can's deformation.

Goal:
The goal of this test is to determine the size of the dents created during drops, and the differences between thick and thin substrate dent deformation. Apart from this it will also show where the drops occur.

Research question:

- What is the limit of the can in regards to fall damage, when is it no longer possible to reuse the packaging?

Materials needed:
During this research, standard test cans, as described in appendix M, were utilised. At the time of the project, it was not possible to obtain a thick and thin PP substrate, so only PET is used for the coating of this test. Since the tests are performed primarily to observe the deformation and not the performance of the coating, it has been determined that only the PET coating would be sufficient.

In addition to the cans used in this study, there were also lids used. These lids are not made from Protact® because it is not possible to make them from Protact® at this time. In addition, this study required a filling for the filled cans. The dry food item utilised during the drop test was coffee beans. It was anticipated that coffee beans would be the heaviest of the dry products that could be packaged in Protact® containers.

Setup:
Prior to conducting any tests, an undamaged can was scanned with a 3D scanner. This can will be utilised to compare dropped cans. Figure 51 depicts the drop test configuration.

Due to the holes at the base of the drop tower, it was decided to place a tile there. As the tiles were quite rough, this would also simulate the drops when they appeared outside the house. There is a close-up of the tile in figure 52.

Figure 53 depicts the setup for the straight drop, while Figure 54 depicts the setup for the oblique drop.

Figure 51: Setup drop test (drop tower)

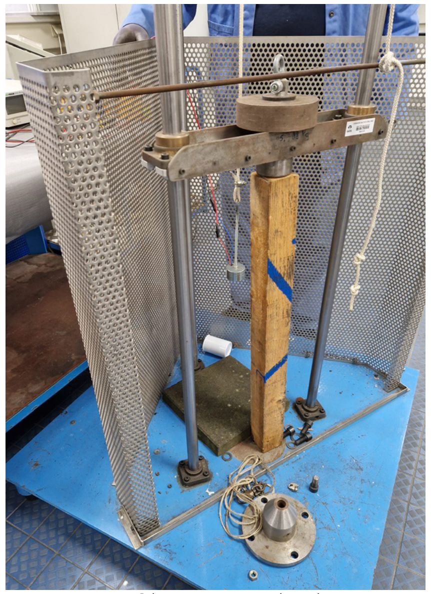


Figure 52: Close up with tile

Figure 53: Setup straight drop

Figure 54: Setup oblique drop

Figure 55 shows the 3D scan configuration. The manual scanning of the cans took approximately 10 to 15 minutes. After being scanned, the documents required processing before they could be utilised. As a result, it was decided not to scan every can that was dropped, but only the ones with the greatest deformation and a few for comparison.

Figure 55: Setup oblique drop

Tests performed (+ results):
Test 1 – Empty cans dropped from 0.5m, 1x drop
In figure 56 the results can be found for all four variations. These are straight drop thick and thin, and oblique drop thick and thin.

Figure 56: Test 1 (0,5m, 1x, empty)

Test 2 – Empty cans dropped from 0.5m, 5x drop
In figure 57 the results can be found for all four variations.

Figure 57: Test 2 (0,5m, 5x, empty)

Test 3 – Empty cans dropped from 0.5m, 10x
In figure 58 the results can be found for all four variations.

Figure 58: Test 3 (0,5m, 10x, empty)

Test 4 – Filled cans dropped from 0.5m, 1x drop
In figure 59 the results can be found for all four variations.

Figure 59: Test 4 (0,5m, 1x, filled)

Test 5 – Filled cans dropped from 0.5m, 5x drop
In figure 60 the results can be found for all four variations.

Figure 60: Test 5 (0,5m, 5x, filled)

Test 6 – Filled can dropped from 0.5m, 10x drop
In figure 61 the results can be found for all four variations.

Figure 61: Test 6 (0,5m, 10x, filled)

These cans were scanned as reference, to have a measurement of a can in between low and high damage. Results can be seen in figure 62 and 63.

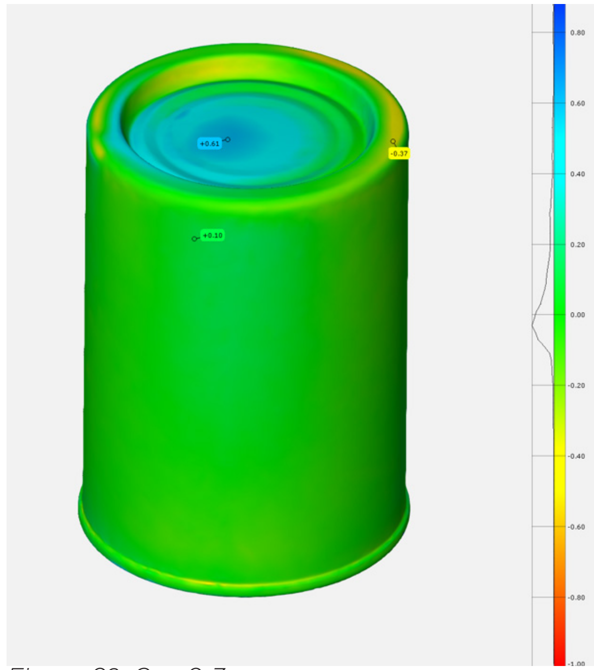


Figure 62: Can 6-3

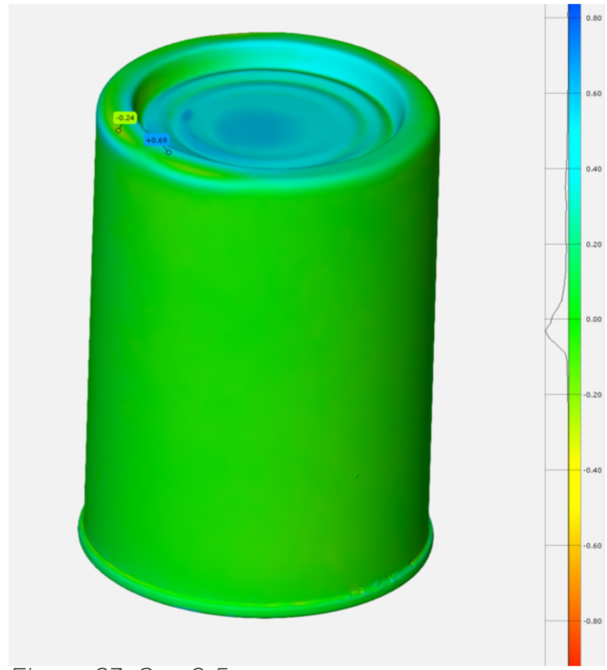


Figure 63: Can 6-5

Test 7 – Empty can dropped from 1m, 1x drop
In figure 64 the results can be found for all four variations.

Figure 64: Test 7 (1,0m, 1x, empty)

Test 8 – Empty can dropped from 1m, 5x drop
In figure 65 the results can be found for all four variations.

Figure 65: Test 8 (1,0m, 5x, empty)

Test 9 – Empty can dropped from 1m, 10x drop
In figure 66 the results can be found for all four variations.

Figure 66: Test 9 (1,0m, 10x, empty)

Test 10 – Filled can dropped from 1m, 1x drop
In figure 67 the results can be found for all four variations.

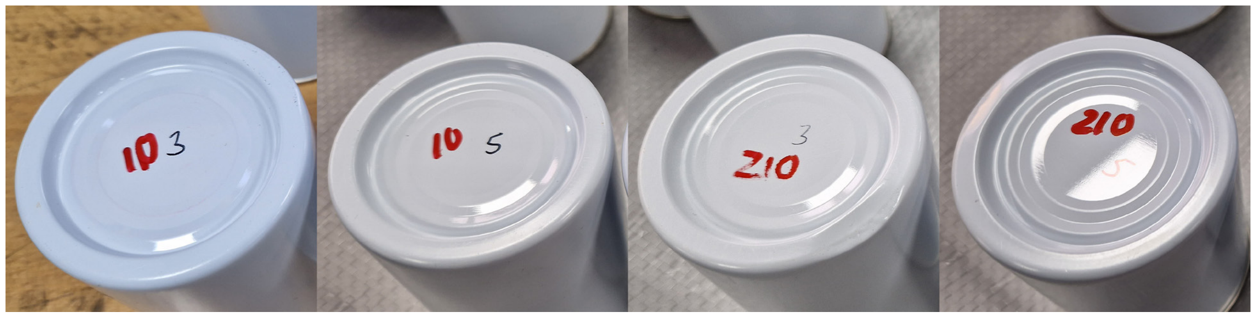


Figure 67: Test 10 (1,0m, 1x, filled)

Test 11 – Filled can dropped from 1m, 4x drop
In figure 68 the results can be found for all four variations.

Figure 68: Test 11 (1,0m, 5x, filled)

Test 12 – Filled can dropped from 1m, 10x drop
In figure 69 the results can be found for all four variations.

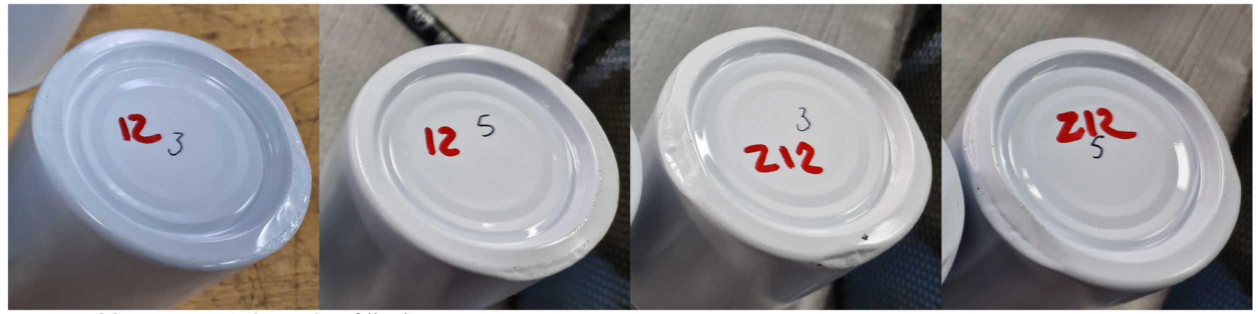


Figure 69: Test 12 (1.0m, 10x, filled)

The cans from this test were also 3D scanned. Results can be seen in figure 70 and 71.

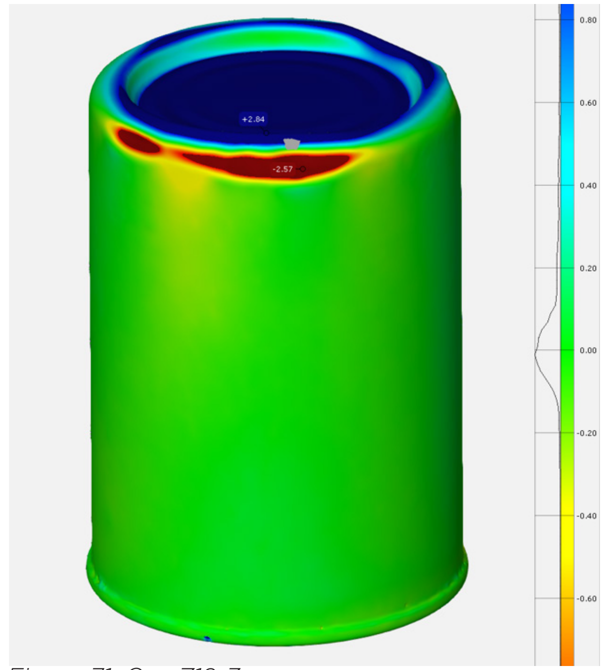


Figure 71: Can Z12-3

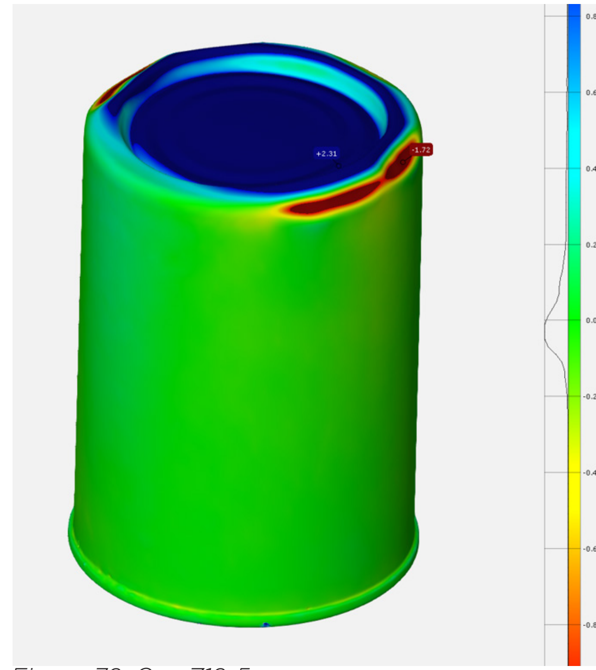


Figure 72: Can Z12-5

Test 13 – Empty can dropped from 1.5m, 1x drop
In figure 72 the results can be found for all four variations.

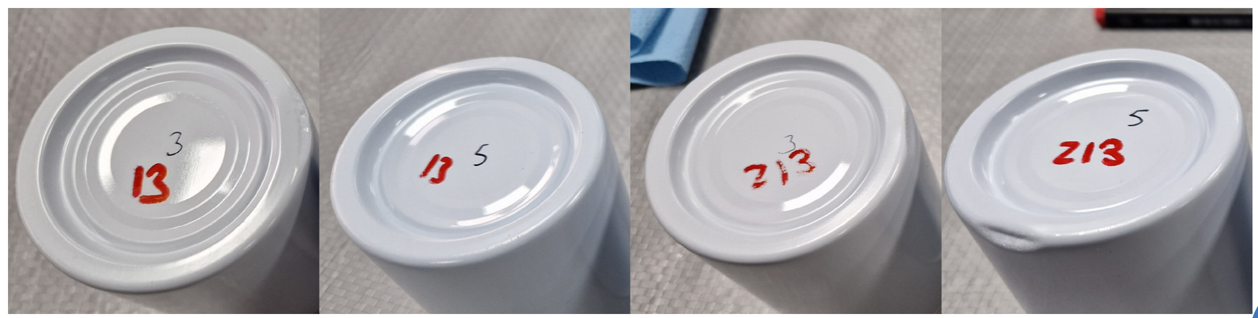


Figure 70: Test 13 (1.5m, 1x, empty)

Test 14 – Empty can dropped from 1.5m, 5x drop

In figure 73 the results can be found for all four variations.

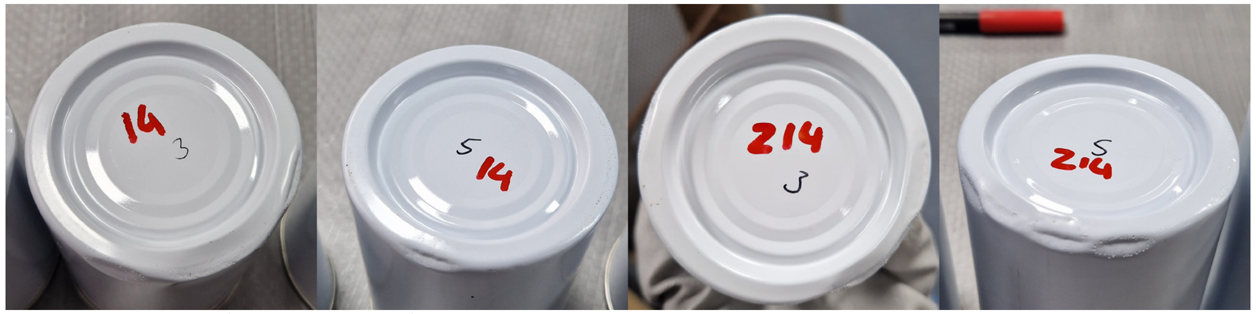


Figure 73: Test 14 (1.5m, 5x, empty)

Test 15 – Empty can dropped from 1.5m, 10x drops

In figure 74 the results can be found for all four variations.

Figure 74: Test 15 (1.5m, 10x, empty)

From this test can Z15-3 and 15-5 were scanned. There has been a mistake as it was planned to scan Z15-5 instead of 15-5, however when reviewing the images it was clear that the can was wrongly named. Results can be seen in figure 75 and 76.

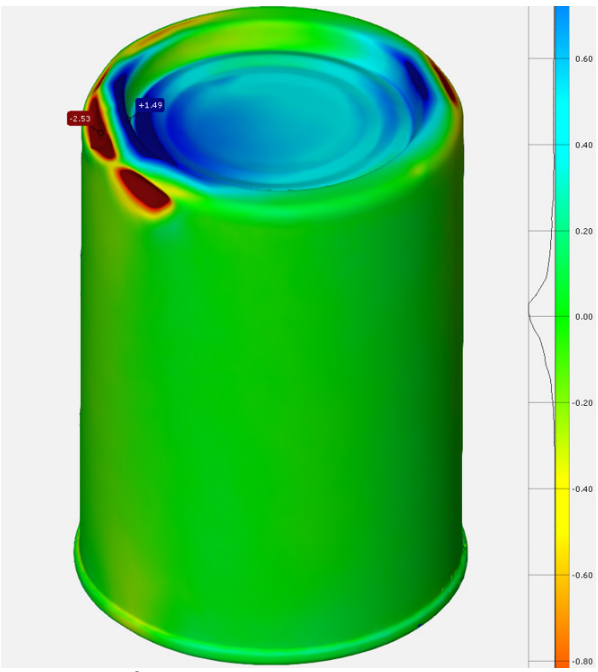


Figure 75: Can Z15-3

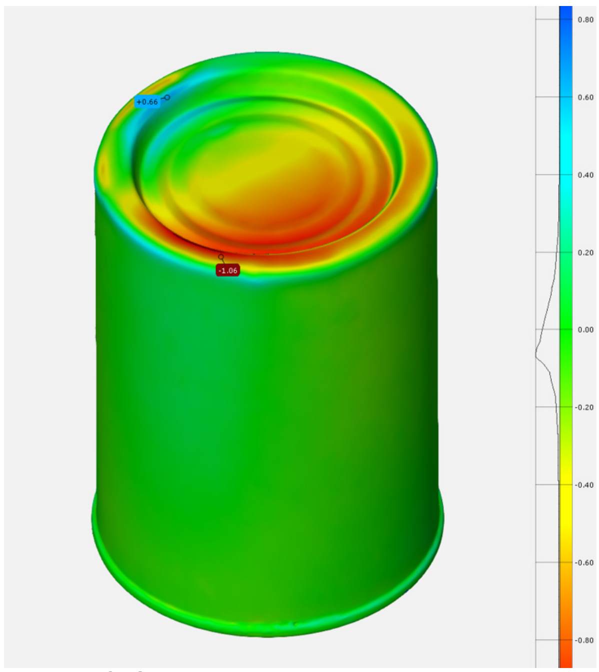


Figure 76: Can Z15-5

Test 16 – Filled can dropped from 1.5m, 1x drop

In figure 77 the results can be found for all four variations.

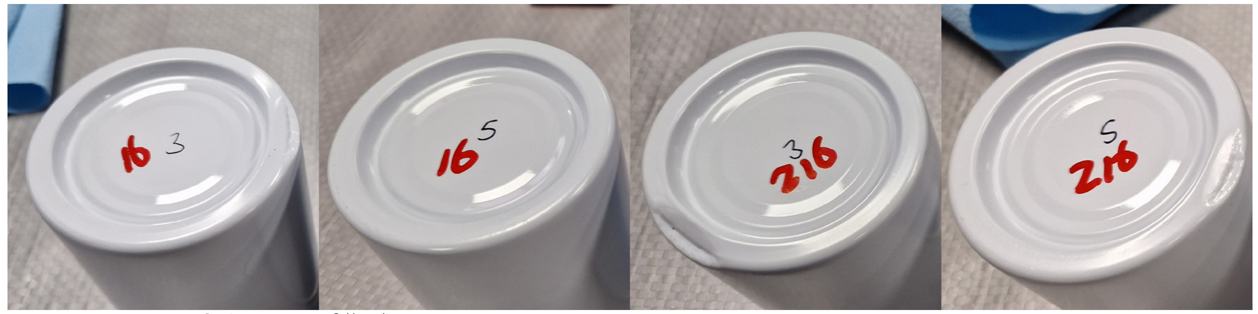


Figure 77: Test 16 (1.5m, 1x, filled)

From this test Z16-3 and Z16-5 were scanned. Results can be seen in figure 78 and 79.

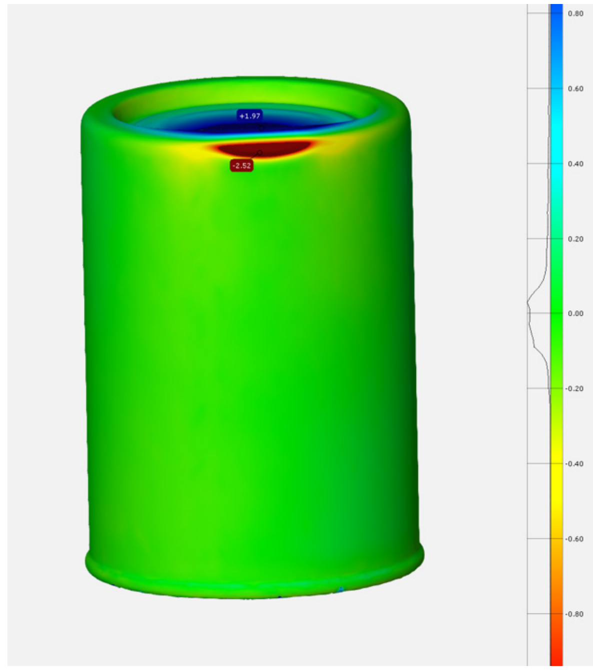


Figure 79: Can Z16-3

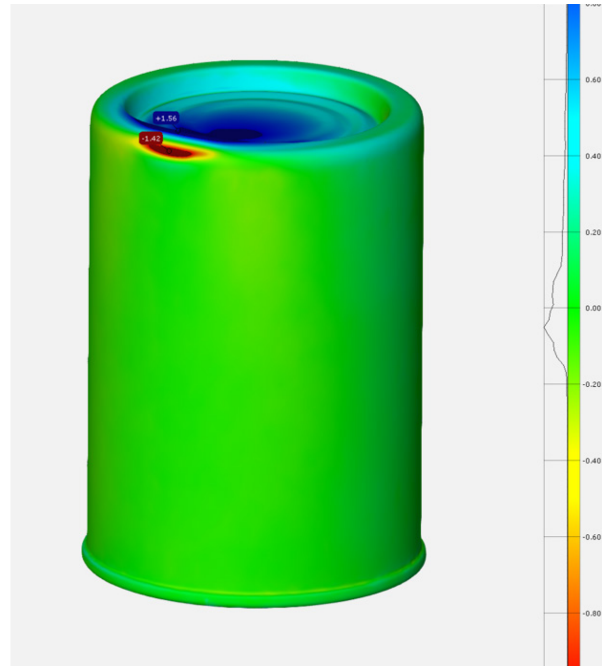


Figure 80: Can Z16-5

Test 17 – Filled can dropped from 1.5m, 5x drop

In figure 80 the results can be found for all four variations.

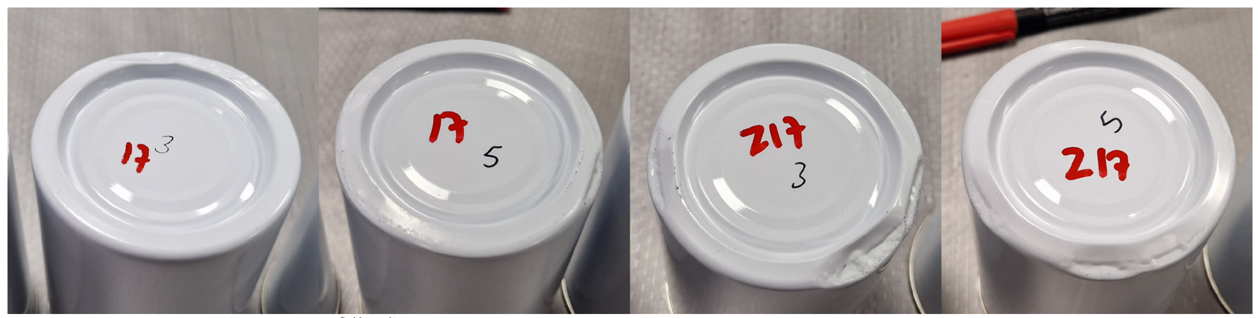


Figure 78: Test 17 (1.5m, 5x, filled)

From this test can Z17-3 and Z17-5 have been 3D scanned. Results can be found in figure 81 and 82.

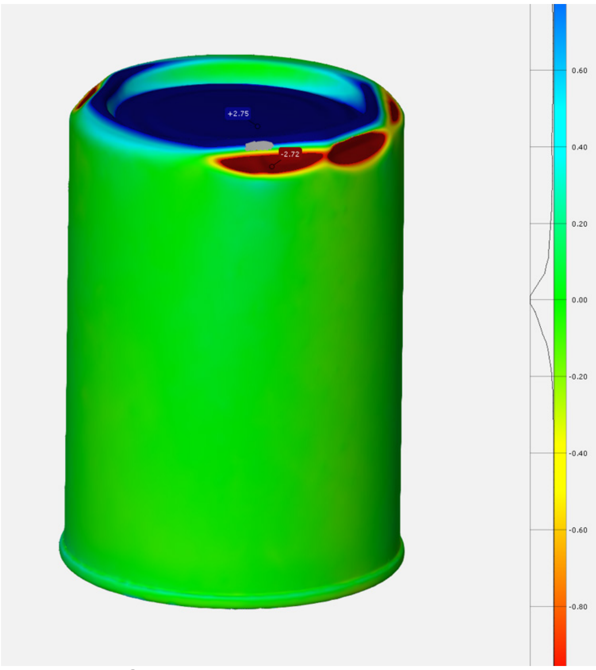


Figure 81: Can Z17-3

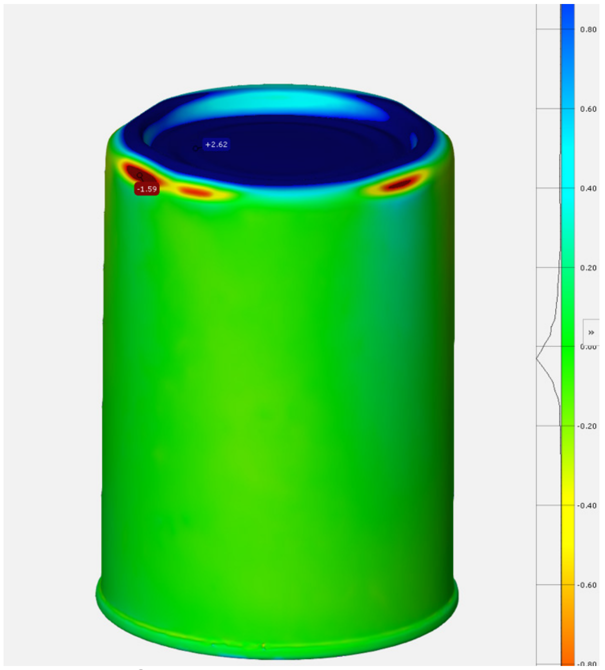


Figure 82: Can Z17-5

Test 18 – Filled can dropped from 1.5m, 10x drop

In figure 83 the results can be found for all four variations.

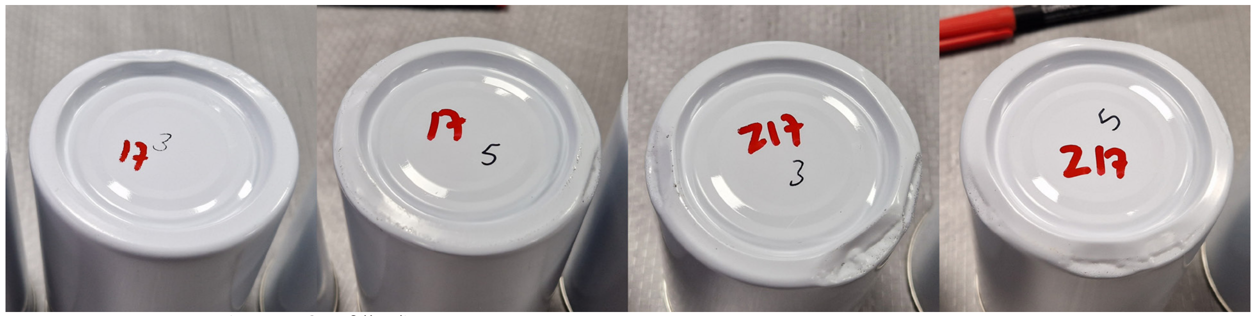


Figure 83: Test 18 (1.5m, 10x, filled)

These cans were are all 3D scanned, since they showed the most damage of the cans that were dropped straight. Results can be seen in figure 84,85,86 and 87.

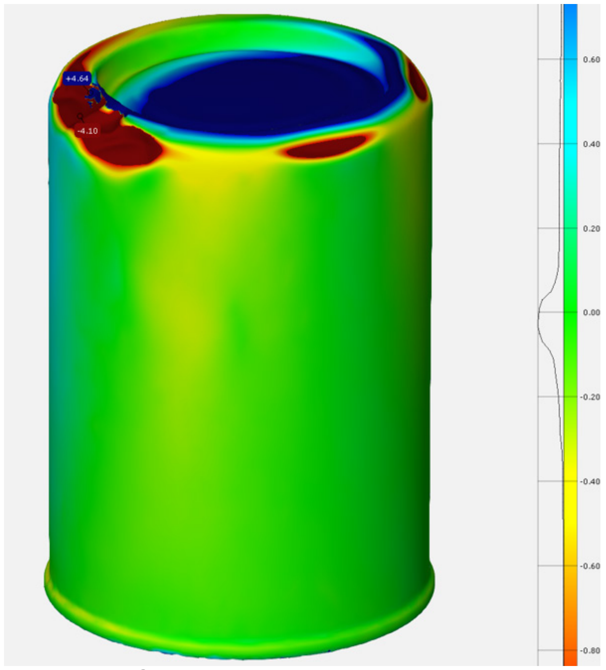


Figure 84: Can 18-3

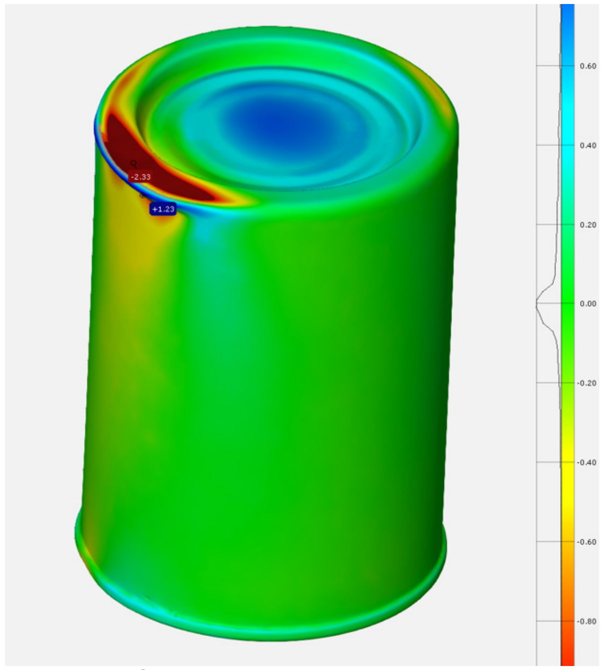


Figure 85: Can 18-5

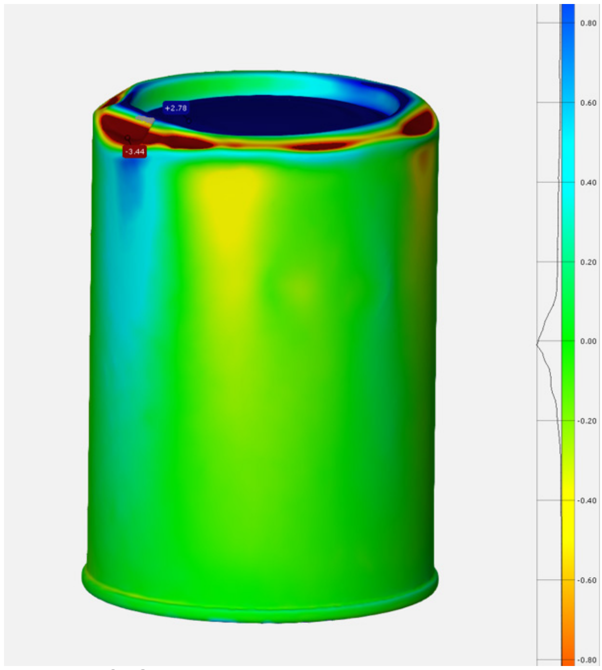


Figure 86: Can Z18-3

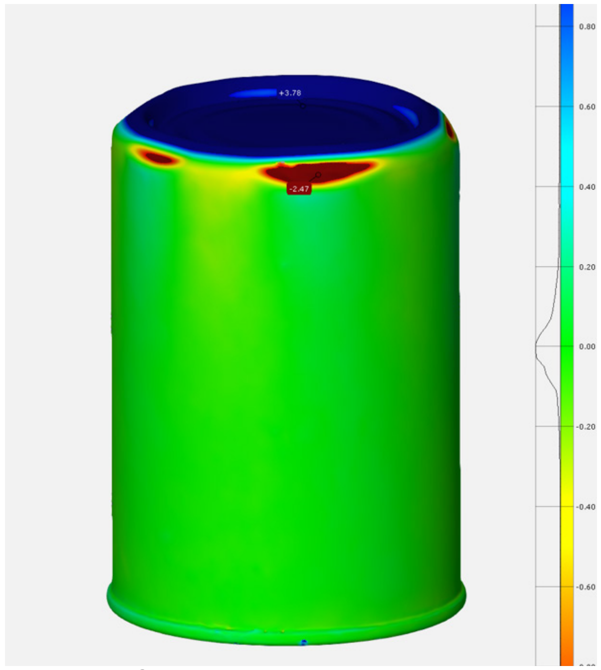


Figure 87: Can Z18-5

Results:
Using the images and measurements from the 3D scans, the deviations of the cans could be compared. Using a scale from 1 to 10, 0 mm deviation to 4.5 mm deviation (see legend, figure 89). It is possible to distinguish thin substrate from thick substrate. Figure 88 depicts the results of empty cans. The results of the filled cans are depicted in figure 90.

Thin substrate, straight drop

	1x	5x	10x
0.5m	1	1	1
1.0m	2	3	3
1.5m	4	4	7

Thick substrate, straigth drop

	1x	5x	10x
0.5m	1	1	1
1.0m	2	2	2
1.5m	2	3	4

Thin substrate, oblique drop

	1x	5x	10x
0.5m	1	2	3
1.0m	2	5	6
1.5m	3	5	7

Thick substrate, oblique drop

	1x	5x	10x
0.5m	1	2	3
1.0m	3	4	5
1.5m	3	5	7

Figure 88: Results empty cans droptests

Legend	Deviation (mm)
1	0
2	0,5
3	1
4	1,5
5	2
6	2,5
7	3
8	3,5
9	4
10	4,5

Figure 89: Legend

Thin substrate, straight drop

	1x	5x	10x
0.5m	1	1	2
1.0m	2	3	5
1.5m	3	5	10

Thick substrate, straigth drop

	1x	5x	10x
0.5m	1	1	2
1.0m	1	2	4
1.5m	2	4	5

Thin substrate, oblique drop

	1x	5x	10x
0.5m	1	3	4
1.0m	3	5	7
1.5m	6	6	8

Thick substrate, oblique drop

	1x	5x	10x
0.5m	1	2	3
1.0m	2	3	5
1.5m	3	4	6

Figure 90: Results filled cans droptests

As shown in the figures, there is a clear distinction between thick and thin substrates. Maximum deviation in millimetres between thick and thin substrate is 2.2 millimetres. This difference is significant. In addition, it is possible to distinguish between straight and oblique drops, as well as between thick and thin drops.

Therefore, selecting a thicker substrate will result in a significant difference in packaging dents. Depending on the number of accepted dents, either option could be selected. Based on the results, the thicker substrate will last longer than the thin substrate. Additionally, the thick and thin substrates should be compared in terms of their sustainability.

Appendix P: Handling

Handling the packaging is a crucial step in the utilisation of the product. As this is the point of contact between the packaging and the consumer, there should be no visual impairments. During the handling of the packaging, the material may become scratched. This can be caused, for example, by a consumer using a knife to scrape out the remaining product. During this test, the worst-case scenario will be examined. Which force, when a consumer handles the packaging with a knife, renders the packaging unusable? (will go through the layers and exposes the steel).

Goal:
The goal of this test is to see how much force the material can handle, from a sharp tool.

Research question:

- What is the maximum force that can be applied on the packaging before it is no longer useable?

Materials needed:
As described in the general setup appendix, test sheets of Protact® were used for this. As scratch testing is only possible on flat sheets and not on cylindrical shapes. The coating on the sheet will consist of PET and PP, the same materials used for microscopic analysis.

Setup:
This analysis will utilise a scratch table, as depicted in figure 91. The sheets depicted in the image were used to demonstrate the effect of the scratching table. In figure 92 the point that was used to scratch can be seen in a close up.

Figure 91: Scratch table

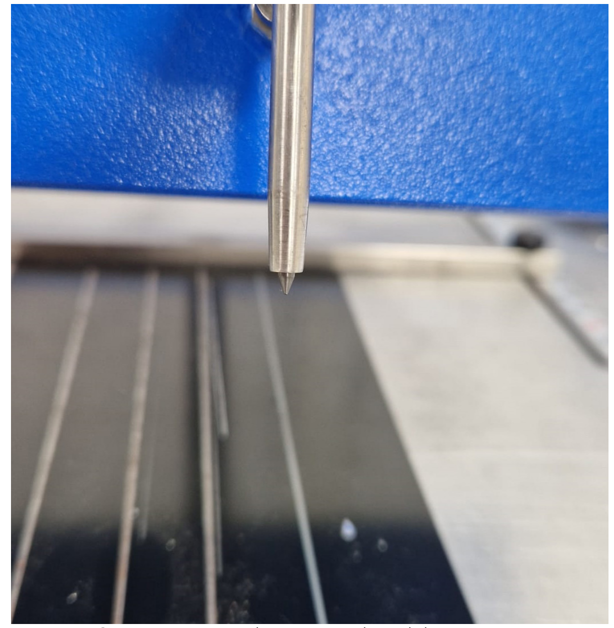


Figure 92: Point on the scratch table

A sharp pin is used to trace over the material on the table. The weight can be adjusted between 2 N and 40N. This provides sufficient precision for determining the scratch resistance of materials.

Tests:
Test 1 – Perform scratch test with 2N
This test has been performed with PP and PET. Each of the following test has first been performed with PP. Afterwards using the information gathered from this results it was possible to exclude some test with PET. For PET the decision has been made to start with 10N after this test because there was barely any line visible, while with PP this was the case.

Test 2 – Perform scratch test with 4N
This has been performed with PP.

Test 3 – Perform scratch test with 6N

This test has been performed with PP.

Test 4 – Perform scratch test with 8N
This test has been performed with PP.

Test 5 – Perform scratch test with 10N
This test has been repeated for PP as well as PET.

Test 6 – Perform scratch test with 12N
This test has been repeated for PP as well as PET. For PET this test has been repeated several times, as this seemed to be the breaking point for PET. Out of several test the PET layer has been damaged 2 out of 6 attempts.

Test 7 – Perform scratch test with 14N
This test has been repeated for both PP as well as PET.

Test 8 – Perform scratch test with 16N
This test has also been repeated for both PP as well as PET.

Results:
In figures 93 and 94, the sheets utilised during the research are displayed. Three white sheets are visible in figure 93; this is the PET coating (with a thickness of approximately 20 m), and two transparent sheets made from polypropylene (PP) are visible in figure 94 (with a thickness of around 40 um). As stated previously, multiple measurements were taken at a force of 12N from the PET coating side. This is due to the varying results that were displayed during the test. Which can be seen in the subsequent section and the relating images.

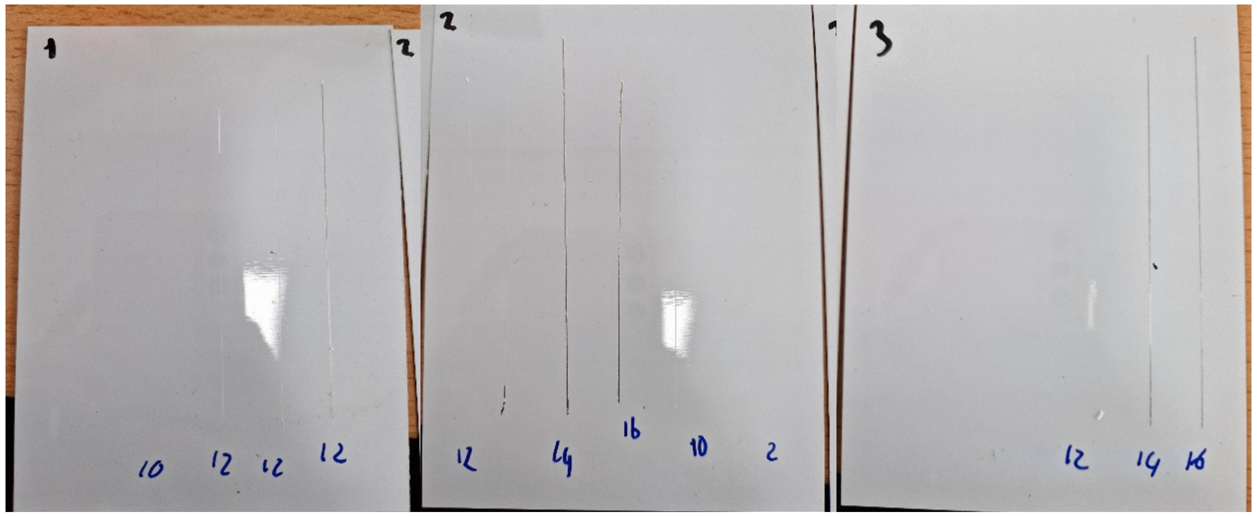


Figure 93: Scratch sheets PET

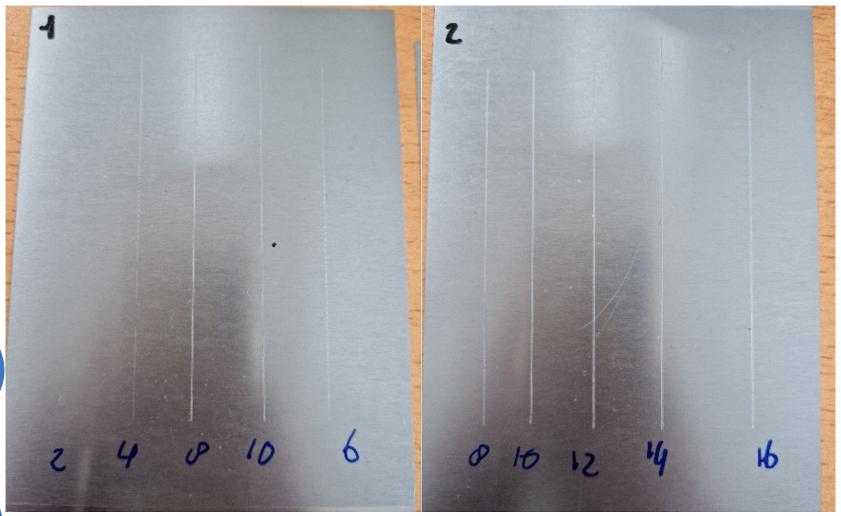


Figure 94: Scratch sheets PP

Using a depth measurement machine, the depths of the scratches have been measured; figure 95 depicts the setup. Henri Kwakkel, the supervisor, has assisted with the measurement by using the machine. The results were approved by the supervisor.

Figure 95: Setup measurements

From these measurements, the following findings emerged. The first intriguing discovery is the distinction in the material's behaviour. PP, for instance, appears to be significantly softer and thus responds differently to the weight applied to it. It appears that the weight pushes the material to the sides, creating a path with the displaced material. In contrast, the weight of PET only creates a small path in the material. In figure 96, a comparison of the two scratches is illustrated.

Figure 96: Illustrated difference in scratches PP vs PET

While examining this behaviour, it is intriguing to note that the outcomes are also quite distinct. PP scratches at lower forces, whereas PET scratches are not visible until higher forces. However, when the force is too great on PET, the surface layer is simply scratched off, leaving the substrate bare. This may cause corrosion of the substrate at those points. PP requires greater force to completely pierce the coating layer.

The results of the measurements of the PP sheets can be found in table 4, while the results of the PET sheets can be found in table 5.

Table 4: Results scratchtests PP Sheets

Force (N)	Surface (mm)	Dent (mm)	Total depth scratch (mm)	Notes
2	0,225	0,225	0	
4	0,225	0,22	0,005	
6	0,221	0,193	0,028	Dotted line
8	0,225	0,212	0,013	
10	0,223	0,203	0,02	

Sheet 2

Force (N)	Surface (mm)	Dent (mm)	Total depth scratch (mm)	Notes
8	0,224	0,21	0,014	
10	0,223	0,204	0,019	
12	0,226	0,198	0,028	
14	0,224	0,186	0,038	Undamaged subtrate
16	0,224	0,185	0,039	Undamaged subtrate

Table 5: Results scratchtests PP Sheets

Force (N)	Surface (mm)	Dent (mm)	Total depth scratch (mm)	Notes
10	0,224	0,217	0,007	
12	0,223	0,219	0,004	
12	0,224	0,219	0,005	
12	0,224	0,204	0,02	Light scratch on substrate

Sheet 2

Force (N)	Surface (mm)	Dent (mm)	Total depth scratch (mm)	Notes
2	0,224	0,224	0	
10	0,224	0,22	0,004	
12	0,224	0,219	0,005	
14	0,223	0,201	0,022	Lane visible in substrate
16	0,224	0,203	0,021	Lane visible in substrate

Sheet 3

Force (N)	Surface (mm)	Dent (mm)	Total depth scratch (mm)	Notes
12	0,225	0,22	0,005	
14	0,224	0,205	0,019	Lane visible in substrate
16	0,223	0,204	0,019	Lane visible in substrate

As is shown in the tables, when subjected to the same amount of force, 12N, PP is slightly damaged, whereas PET has already torn in some cases, exposing the substrate. In excess of 12N, the PET coating has torn and been damaged beyond repair. While PP can withstand forces up to 16N without damaging the coating. In addition, PET's coating is half as thick as PP's, which can also affect the results. However, the behaviour observed during this test will remain the same; the only difference will be that PET will tear at a force greater than 12N.

Several characteristics must be taken into account when determining which coating would be most suitable for a reusable packaging. One of these characteristics is scratch resistance; however, it is possible to view the resistance from two perspectives. The first is the amount of force it can withstand without exposing the substrate, and the second is the nature of the resulting scratches. While the force in this case may be favourable to PET, the type of scratch will be favourable to PP. As it is undesirable for the coating to completely tear when the force applied is slightly above the permissible maximum. This does not appear to be the case with PP. However, PP scratches more easily with smaller forces than PET does.

Which of the two types of material is more advantageous depends on its intended application. Each has advantages and disadvantages in comparison to the other. When deciding which type of material to use, the situation in which it will be used, as well as the results of research on other materials, must be considered.

Appendix Q: Industrial washing (and drying)

This test will determine whether Protact® is compatible with Loop's washing procedure. It must endure this process at least ten times. This will be accomplished using industrial washing machines and the data supplied by Loop. Since Loop's washing and drying line was unavailable at the time, Tata Steel's industrial washing line was chosen for this test. These are heavy-duty washing machines used in can production lines. The packaging should withstand washing without visual impairment or material damage.

Goal:
The goal is to test the maximum amount of times for the material to be washed (and whether it can survive 9 times). Another goal is to test the maximum amount of times for the material to be dried.

Research question:
What is the maximum amount of times for Protact® to be able to be washed?
Is this affected by damages to the material such as dents and scratching?
What is the maximum amount of times for Protact® to be able to be dried?
Is this affected by damages to the material such as dents and scratching?

Materials needed:
For this test, multiple cans ae required. Cans made of PET and PP. Ideally on the interior and exterior. Since it will be possible to measure the water absorption on the packaging's interior. For this test, three cans will be used at each temperature. These cans will be washed up to ten times; one can will be washed once, another will be washed five times, and the final can will be washed ten times. This allows for a side-by-side comparison of the cans after one, five, and ten washes. It is crucial that the edges of these cans are sealed so as not to interfere with the results of the tests. Since it is already known that exposed edges will corrode, as stated in multiple meetings with colleagues throughout the project, the exposed edges will be protected. During tests, the water absorption can be measured using an EIS device, as described in [34] by colleagues.

Setup:
As previously stated, the industrial washing machine from Tata Steel will be used for this test. It will be configured with the same settings as Loop. To be able to simulate as closely as possible the washing trials from Loop.

Before the test, one can will be used as the null measurement (to be able to be compared to the cans that have been washed). Aside from this, every washing cycle will include one container with the electronic sensor. This sensor will be able to measure the material's water absorption when in contact with water. This provides information about the substance throughout the process.

After the tests are completed, some cans will be sent to a laboratory for further analysis. This laboratory will determine whether or not the packaging has been properly cleaned, and whether or not bacteria remain after cleaning. TLR international laboratories would be able to perform the test (the test have also been discussed with them). In addition, some samples will be examined with the Raman to determine whether the material has changed.

Test (+ results):
Test 1 – One washing and drying cycle (pre-wash (soaking) 10 minutes at 60 degrees, washing 20 minutes at 80 degrees, drying for 20 minutes at 80 degrees)

Test 2 – Five washing and drying cycles (pre-wash (soaking) 10 minutes at 60 degrees, washing 20 minutes at 80 degrees, drying for 20 minutes at 80 degrees)

Test 3 – Ten washing and drying cycles (pre-wash (soaking) 10 minutes at 60 degrees, washing 20 minutes at 80 degrees, drying for 20 minutes at 80 degrees)

Test 4 – One washing and drying cycle (pre-wash (soaking) 20 minutes at 70 degrees, washing 30 minutes at 80 degrees, drying for 30 minutes at 80 degrees)

Test 5 – Five washing and drying cycles (pre-wash (soaking) 20 minutes at 70 degrees, washing 30 minutes at 80 degrees, drying for 30 minutes at 80 degrees)

Test 6 – Ten washing and drying cycles (pre-wash (soaking) 20 minutes at 70 degrees, washing 30 minutes at 80 degrees, drying for 30 minutes at 80 degrees)

Test 7 – One washing and drying cycle (pre-wash (soaking) 20 minutes at 70 degrees, washing 30 minutes at 80 degrees, air drying)

Test 8 – Five washing and drying cycles (pre-wash (soaking) 20 minutes at 70 degrees, washing 30 minutes at 80 degrees, air drying)

Test 9 - Ten washing and drying cycles (pre-wash (soaking) 20 minutes at 70 degrees, washing 30 minutes at 80 degrees, air drying)

Appendix R: Water absorption

As stated in the report, this section will explain the research conducted by colleagues from Tata Steel [103]. The research was conducted in order to compare and develop a coating variant with superior water resistance. They began their investigation by comparing a PET and PP variant of Protact®. During the research, a modified version of PET was created, and its results were compared to those of the other two versions.

During this research, the electronic impedance spectroscopy (EIS) technique is utilised. This is a type of technology that measures a material's capacitance. In the case of Protact®, the capacitance of the coating is indirectly measured. Since the substrate of Protact® is composed of steel and the water solution used in these experiments contains 1% acetic acid, it is possible to measure any difference in conductivity and, consequently, coating absorption. When cracks or holes appear in the coating, the conduction between the water and the steel is no longer hindered, and so the change in conduction can be measured. Since the distance between the water and the steel shrinks when holes begin to form, they can also detect when these effects begin to manifest.

In order to measure these effects in the cans, a small EIS device had to be inserted through a hole drilled in the can's bottom. The can is then sealed, and the cans containing the measuring device were heated. This technology enables the device to measure differences in capacitance and conductivity when the material is heated.

The experiment was designed to simulate sterilisation and pasteurisation. To determine which coating would be the most effective. As previously stated, the cans are filled with a 1% acidic acid solution with a 5% headspace. For pasteurisation, the contents of the cans are heated to 368 K (94.85 degrees) for one hour. Additionally, the sterilised cans are heated to 396 K (122.85 degrees) for 1 hour.

After one test pack, their experiment demonstrates (figure 2 in the paper) that PET performed poorly compared to modified PET and PP. PP demonstrated the lowest levels of discoloration, blister formation, and Fe absorption.

The most interesting graphs from this experiment for this project are figures 11, 13, 14, 15, and 16 [103]. These numbers illustrate the relationship between the capacitance of the specified materials and their temperatures. Their research indicates that for both coatings, there is a point at which material damage becomes irreversible. For PET, the process begins at 360 K (86.85 degrees) while for PP, it begins at 380 K (106.85 degrees).

During a discussion with one of the paper's authors, it became clear that this material's behaviour is a result of PET's transformation following the glass transition. Which typically begin at approximately 350 K (76.85 degrees) for PET. In wet conditions, however, the glass transition temperature is already 330 K (56.85 degrees) because water is a plasticizer. At this point, PET begins to soften, allowing water to pass through the coating and eventually causing irreversible discoloration and substrate corrosion. PP is already in the glass state, as its glass transition temperature is approximately -10 degrees. In addition, PP dislikes water and appears to be hydrophobic. Therefore, PP does not absorb water and prefers to deflect it. PP's irreversible state is due to the fact that the material begins to melt at this temperature. While PET absorbs water and, as a result, suffers irreversible damage much earlier.

During this meeting, additional aspects of PP were discussed, including the fact that PP is stiffer and thus more resistant to deformation (which was became clear in other discussion). Since it requires a considerable force to deform Protact® with a PP coating, lubrication of the sheets are required. PP is also more difficult to print on, so any information that must be printed on the material will be problematic. In addition, the scratch test revealed that PP is less scratch-resistant than PET.

Appendix S: Closures

At this moment there are no steel packaging available that are reused several times. Thus closures have not been tested several times in a row. For that reason this test will also be performed.

Goal:
The goal is to determine whether Protact® is suitable to be opened and closed multiple times without damage to the coating.

Research question:
- How often can a Protact® can be opened and closed?

Materials needed:
For this test there was limited material available. As has been stated in the appendix X (general setup material tests).

Setup:
This test will exist out of manually opening and closing the screw thread packaging several times. It would have been too expensive to create an automated system to open and close the packaging for just two cans. Due to that reason it has been decided to manually perform the tests, the test have been executed by Menno de Bruine.

In order to take images of the cans at the same locations it was needed to mark the spots. This has been done using a marker. For the first can the image were taken after each 10 times of opening and closing the can. These images were made using a microscope, to be able to see any small damage that has been created.

Test 1 – Open and close 10 times
With can number 1 the opening and closing occurred at the exact same spot each time, while with can number 2 this was randomized.

Test 2 – Open and close 20 times

Test 3 – Open and close 30 times

Test 4 - Open and close 40 times

Test 5 - Open and close 50 times

Test 6 - Open and close 60 times

Test 7 - Open and close 70 times

Test 8 - Open and close 80 times

Test 9 - Open and close 90 times

Test 10 - Open and close 100 times

Results:
This section will show the images taken during the opening and closing of the packaging. First the images from can 1 will be shown and after this can 2.

Can 1
Can 1 has been opened a total of 100 times, with visual check after every 10 times. In the following figures the images taken during this process can be found.

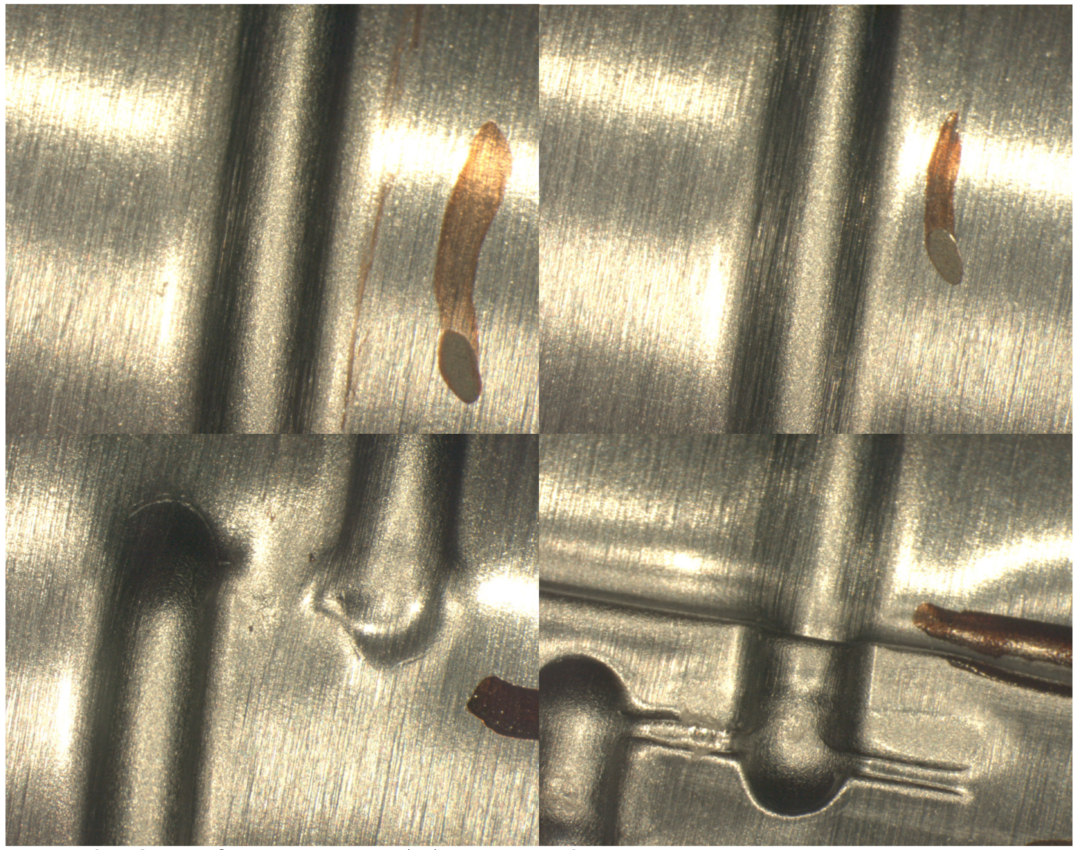


Figure 97: Can 1 after opening and closing can 10 times

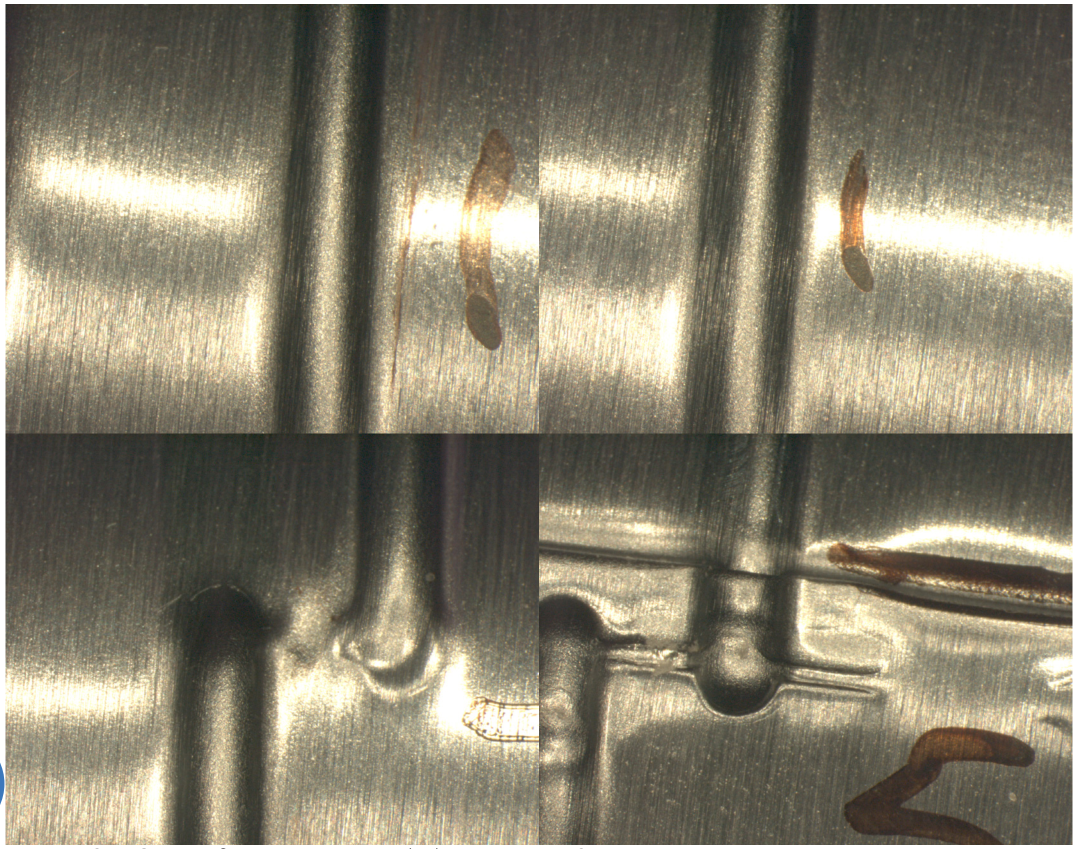


Figure 98: Can 1 after opening and closing can 20 times

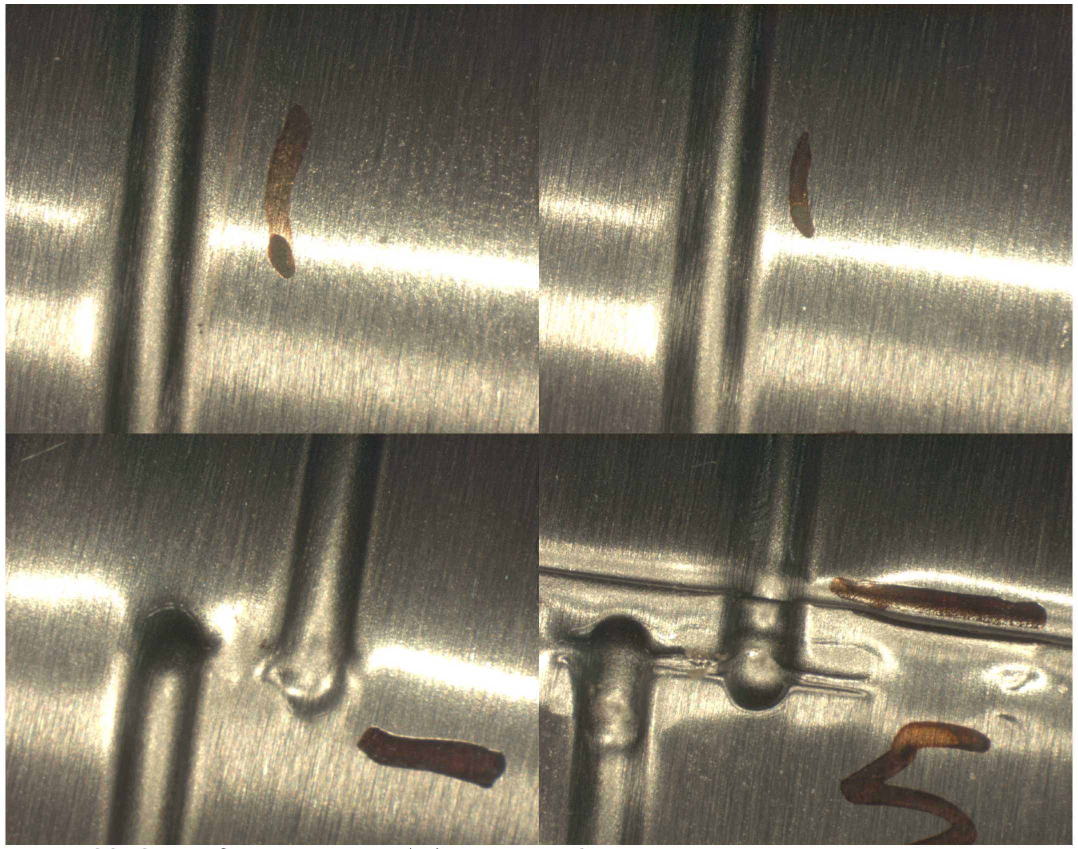


Figure 99: Can 1 after opening and closing can 30 times

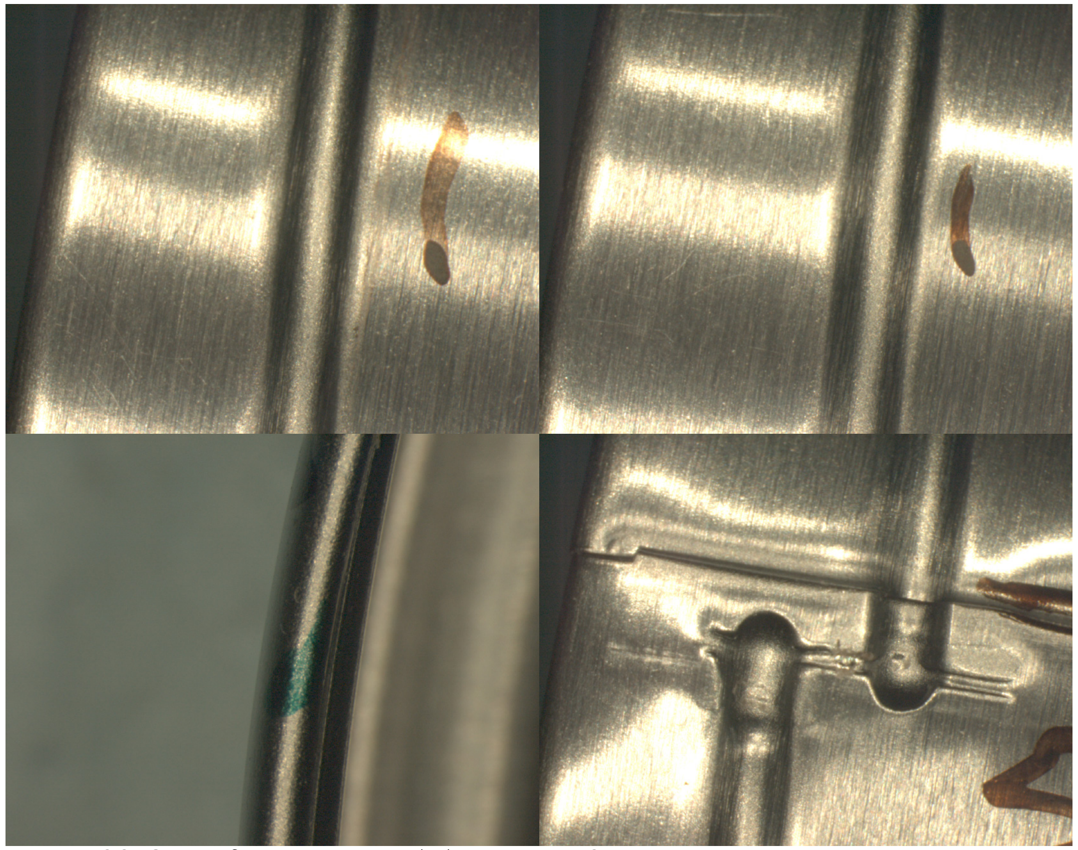


Figure 100: Can 1 after opening and closing can 40 times

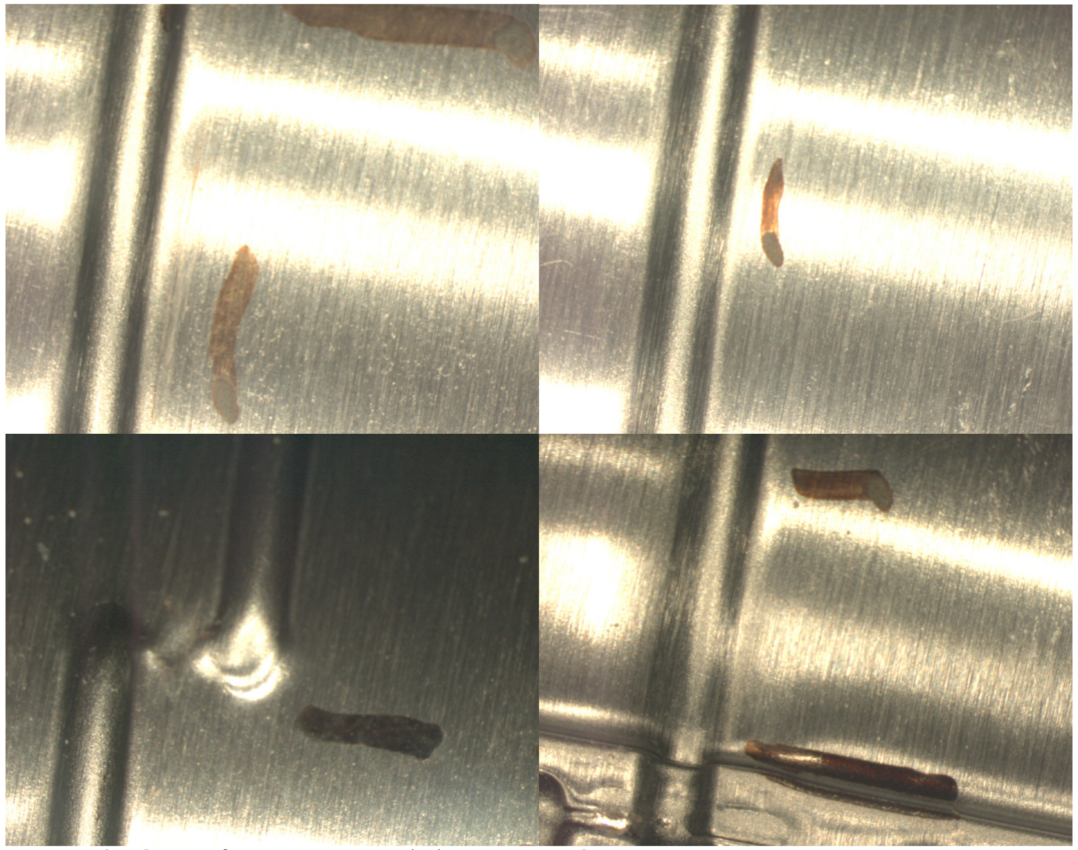


Figure 101: Can 1 after opening and closing can 50 times

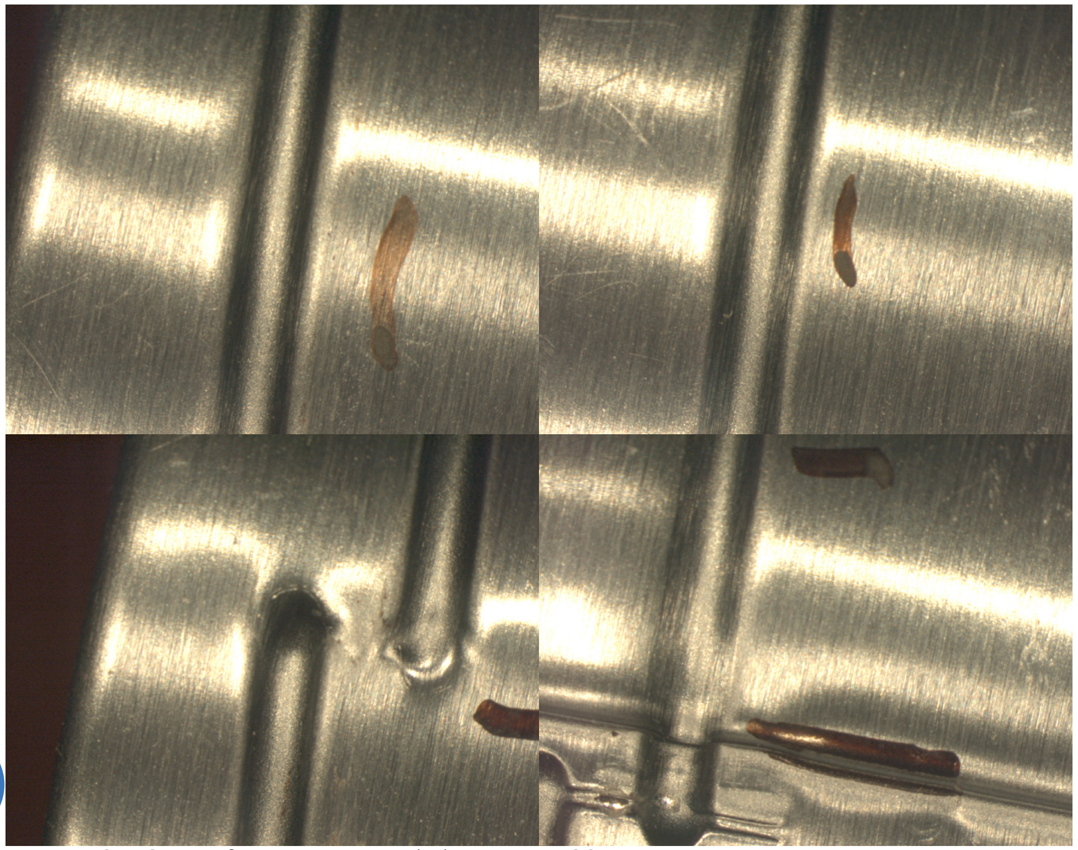


Figure 102: Can 1 after opening and closing can 60 times

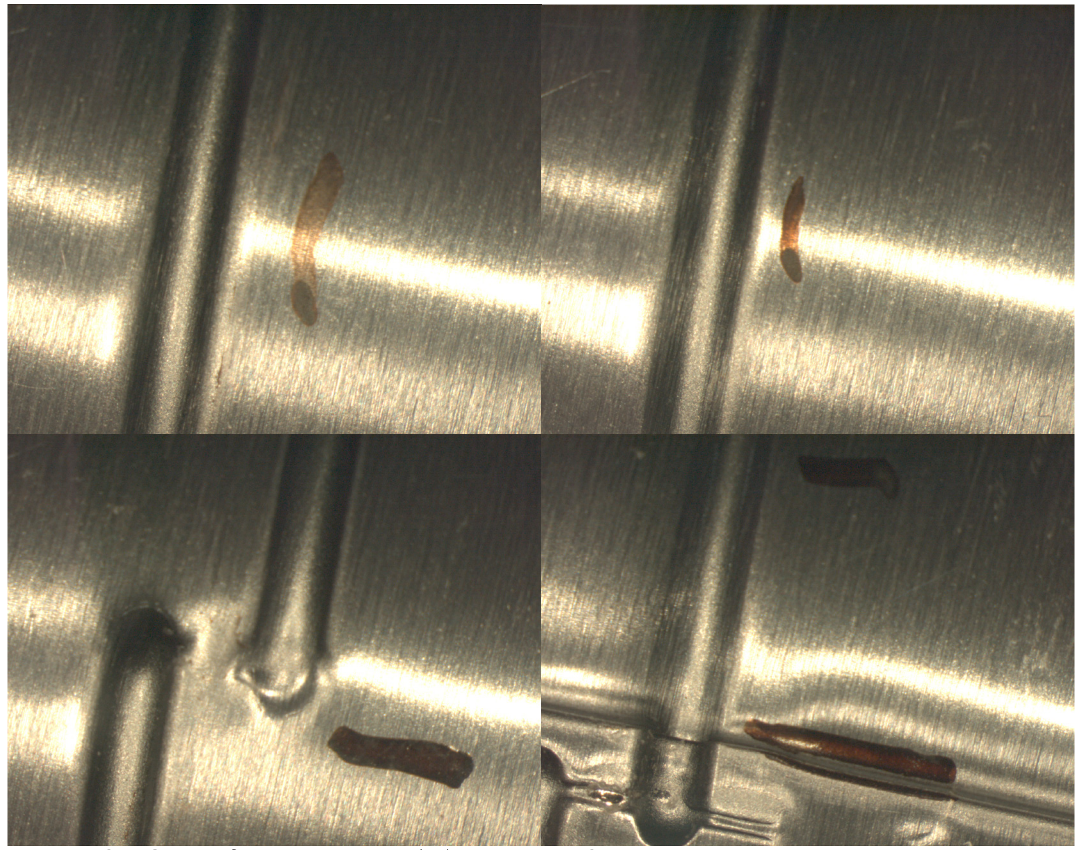


Figure 103: Can 1 after opening and closing can 70 times

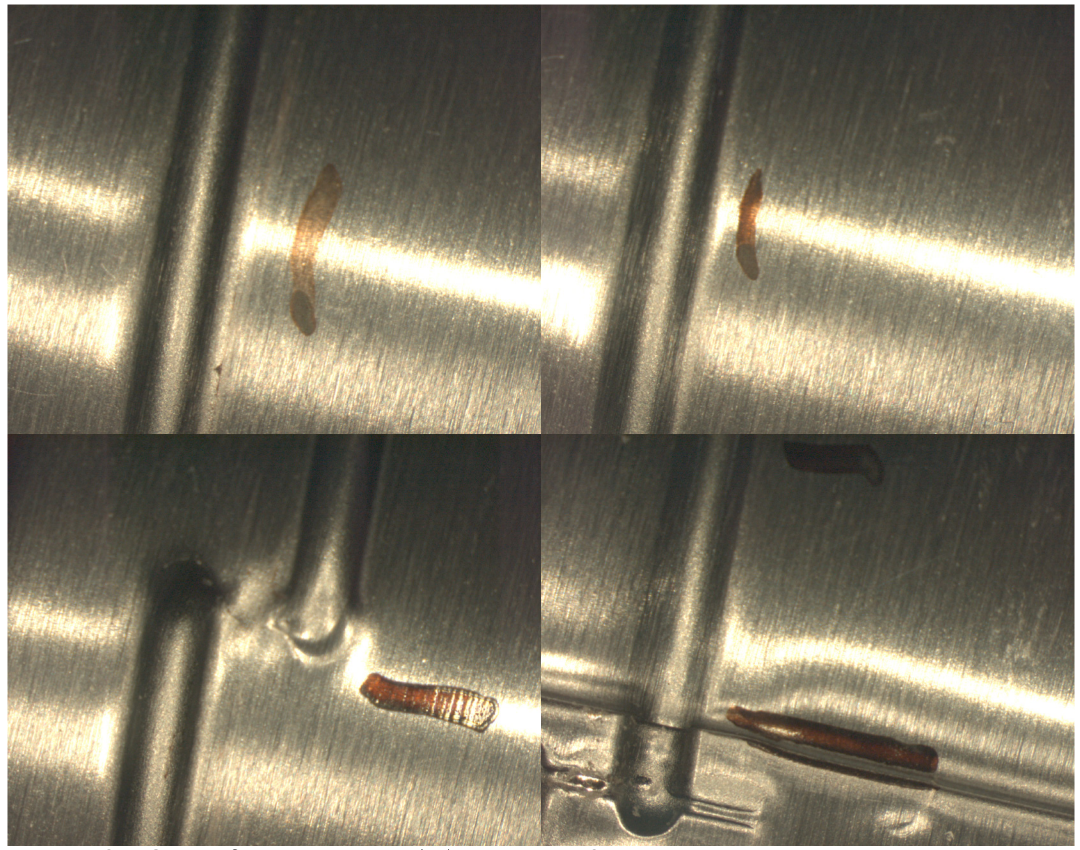


Figure 104: Can 1 after opening and closing can 80 times

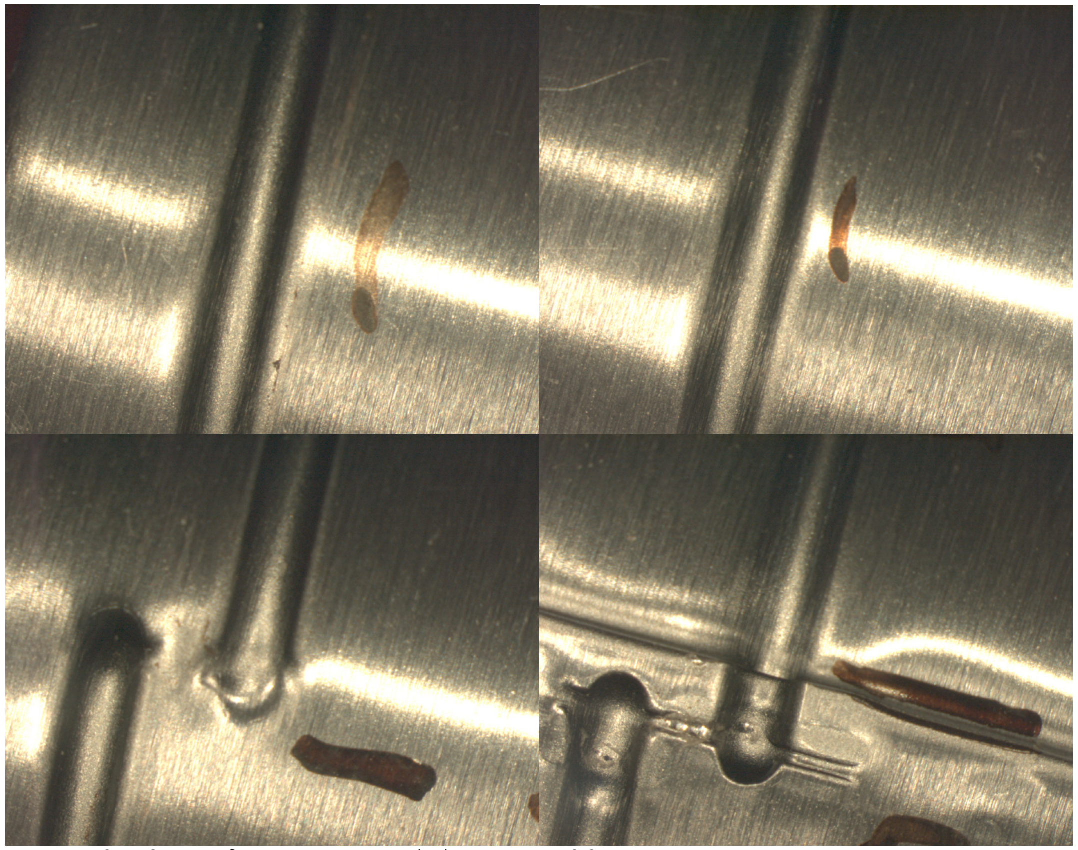


Figure 105: Can 1 after opening and closing can 90 times

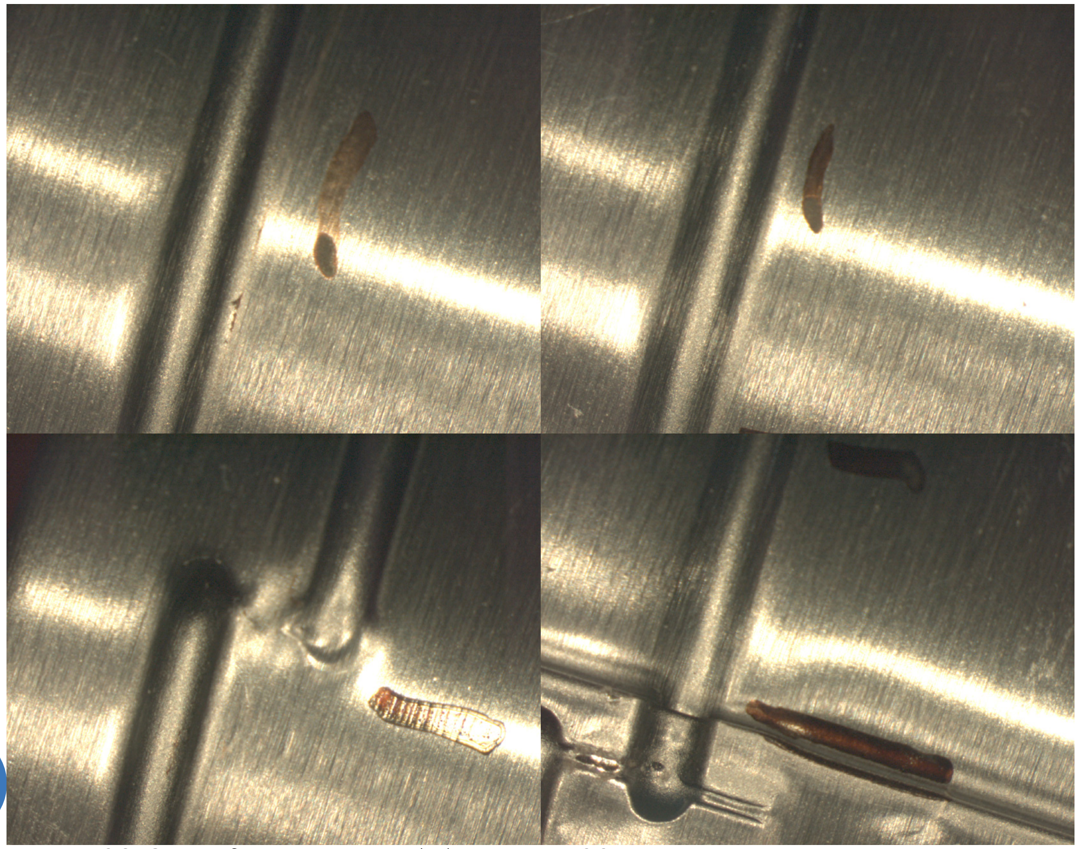


Figure 106: Can 1 after opening and closing can 100 times

Can 2

Can 2 has also been opened a total of 100 times, but the difference is that after every 20 times the can had a visual inspection. Since the damage to the first can was not that much.

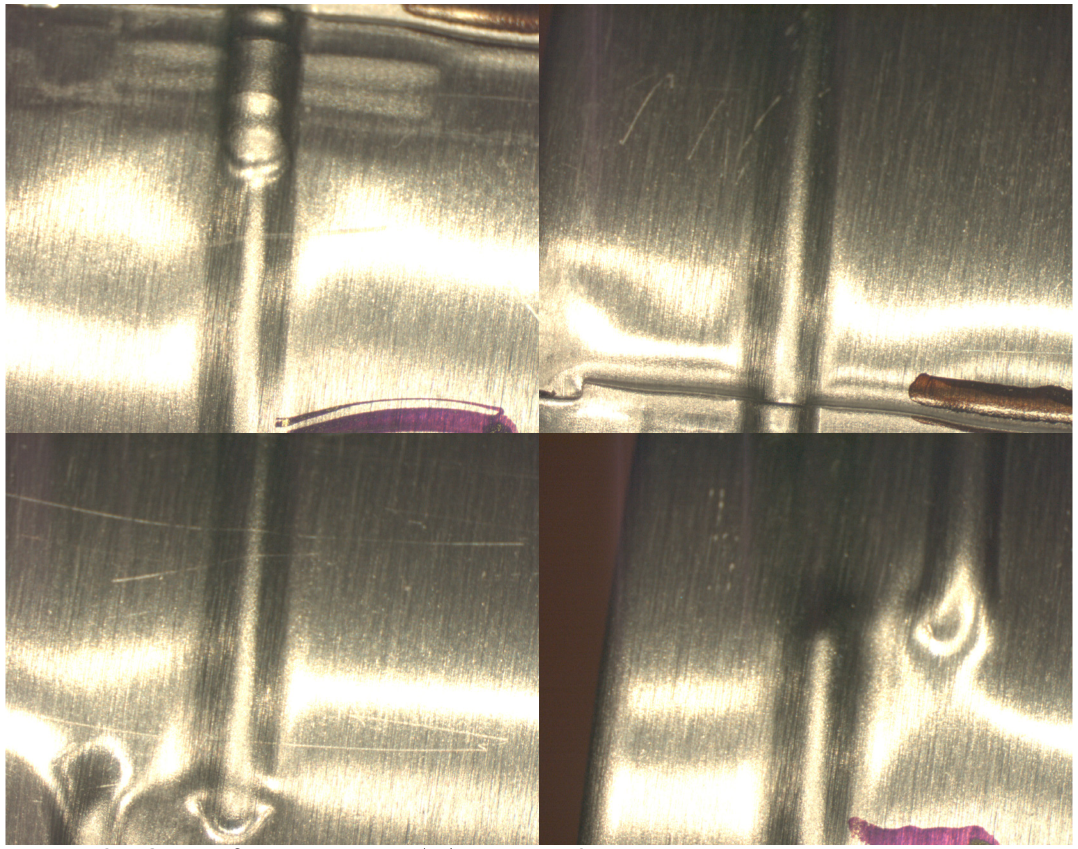


Figure 107: Can 2 after opening and closing can 0 times

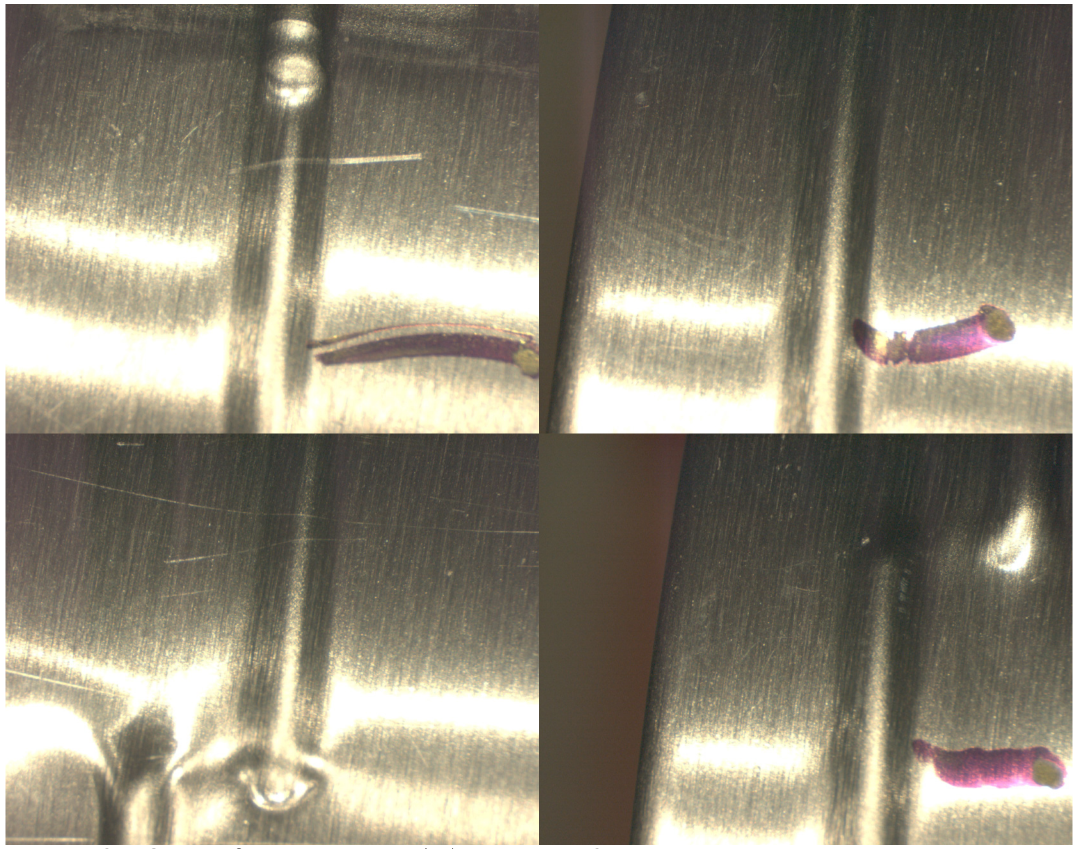


Figure 108: Can 2 after opening and closing can 20 times

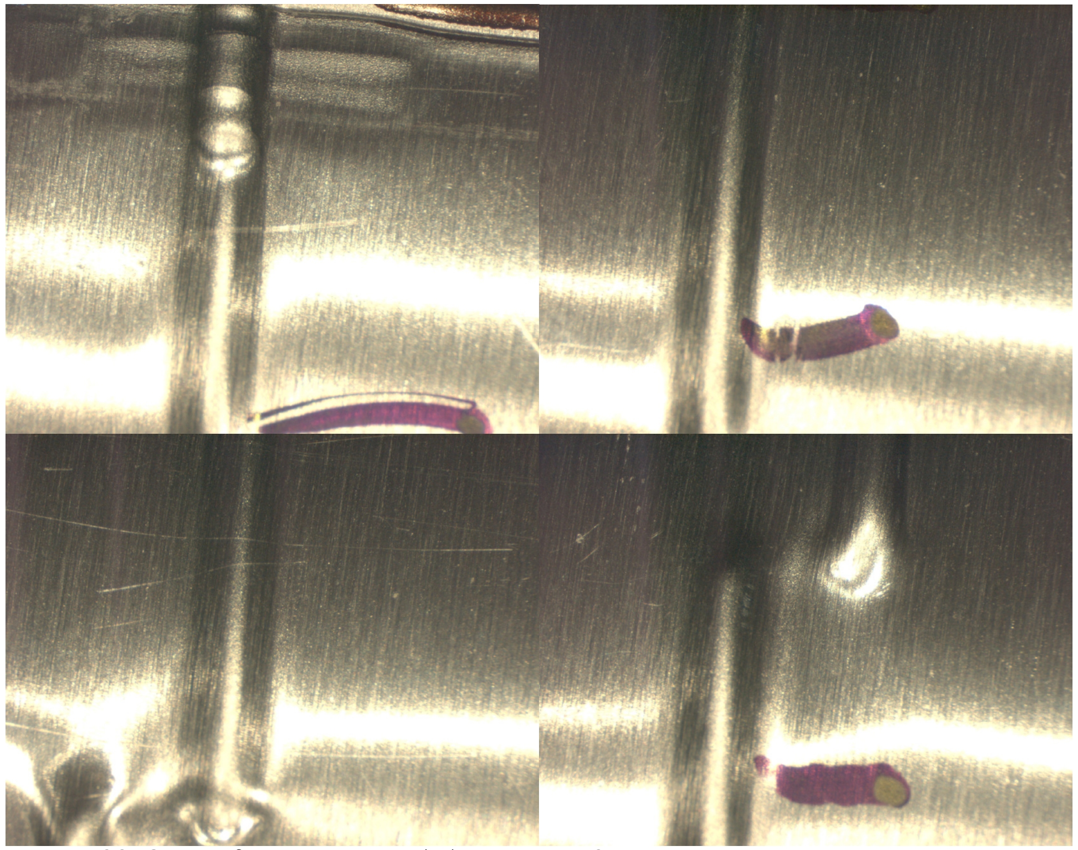


Figure 109: Can 2 after opening and closing can 40 times

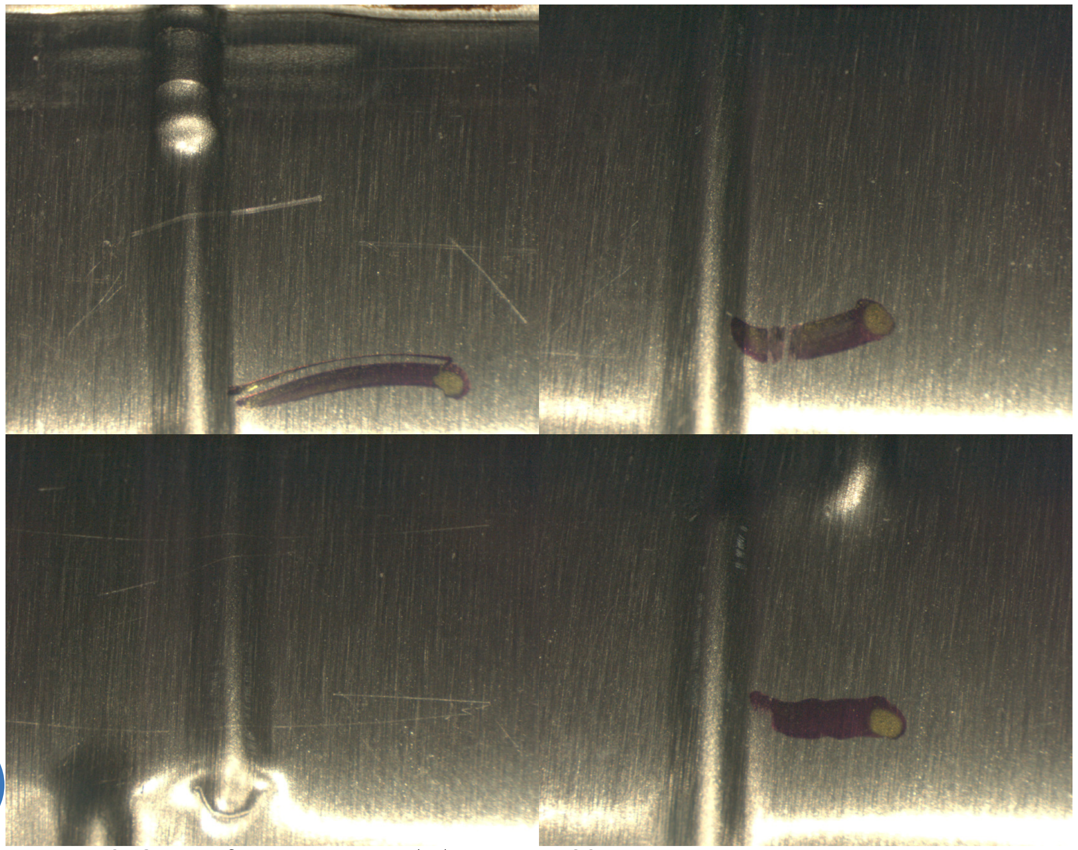


Figure 110: Can 2 after opening and closing can 60 times

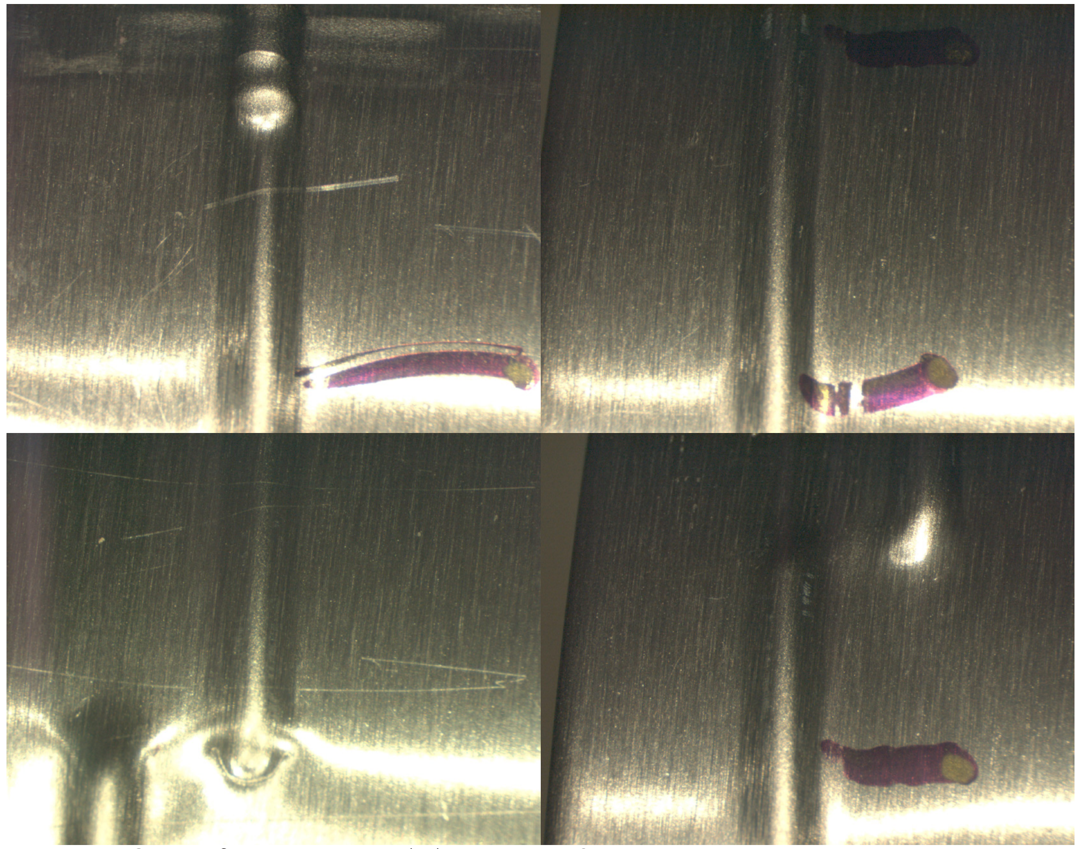


Figure 111: Can 2 after opening and closing can 80 times

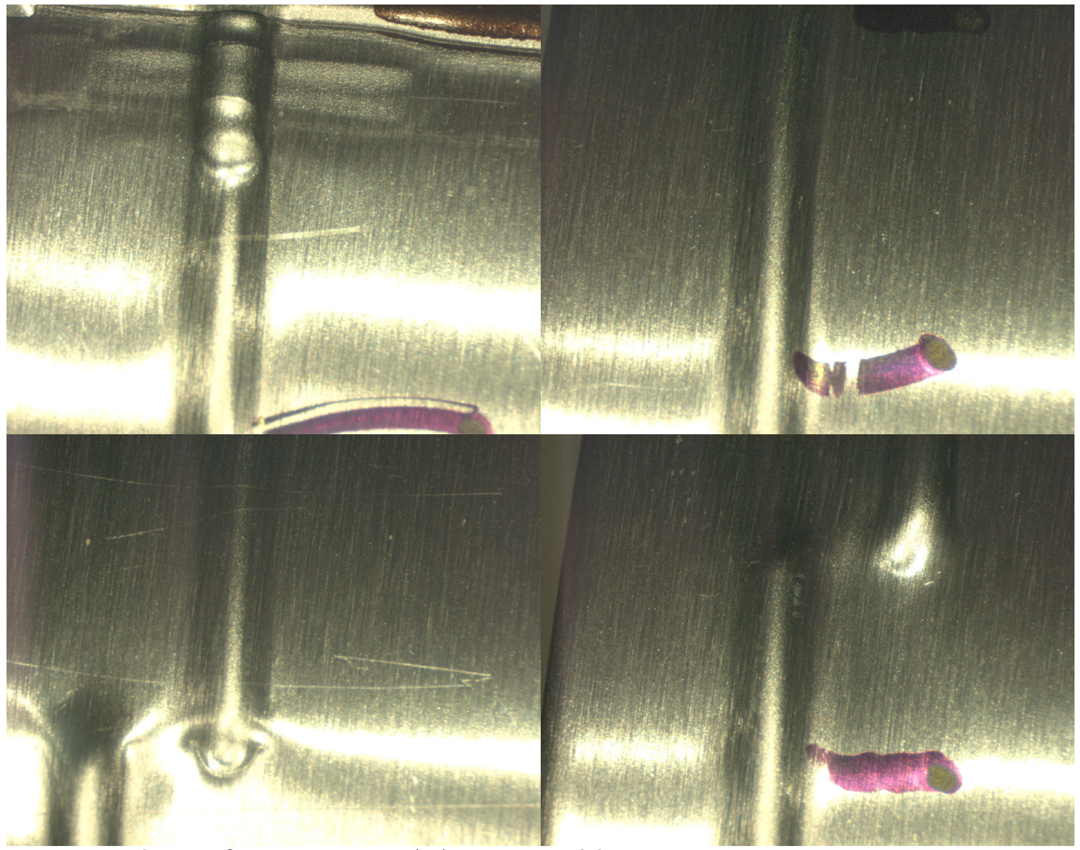


Figure 112: Can 2 after opening and closing can 100 times

The Protact® screw thread closure was evaluated by repeatedly opening and closing each can up to 100 times. Upon examination of the images, the screw thread exhibited almost no visible damage after 100 cycles. However, after 30 cycles of opening and closing the lid on can number 1, minimal damage was observed on the screw thread's edge. After fifty cycles, the damage became more severe. It could not be determined if the damage had penetrated the coating. Based on the scratch test for a PET coating, however, it is unlikely that the entire coating was ripped. In addition, this effect was not observed on the second can, which was opened at random locations to evenly distribute the force.

The Protact® PET coating is capable of withstanding at least 100 opening and closing cycles, based on these observations. To determine the maximum number of cycles for both PET and PP coatings on multiple cans, additional research is required.

Appendix T: List of requirements

The list of requirements will be shown in the following pages.

Starting points							
1.1	R	The packaging should be able to be used with dry food contents.	Other food are also possible but then more research is required.	Test by using heated room and packaging design filled with dry food. If is survives for 2 years in the heated room, then it succeeds.	Tata Steel	8-11-2022	1
1.2	R	The packaging must be designed to be reusable.		Test by refilling and reusing the packaging.	Technology research	23-1-2023	2
1.3	R	The packaging must be designed to be able to store food.		Test by storing food inside the packaging.	Market research	1-9-2023	2

Nmr.	Type: R/W	Explanation	Notes	Test method	Source	Date	Version
1. Functional requirements							
1.1	R	The packaging must be able to survive transportation.	After the packaging has been produced, so from the can manufacturer up until the customer.	Test by recreating transportation environment.	Market research	8-11-2022	1
1.2	R	The packaging must perserve the contents for a minimum of 1 year.	Depending on the kind of food that will be stored in there. Dry foods at least a year.	See R1.1, difference is after 1 years this requirement succeeds.	Market research	8-11-2022	1
1.3	R	When the packaging is sold in-store the packaging must also serve as a marketing tool.	The packaging must sell the product.	Test by looking for graphics, colours, text on the packaging (which enhace the appearance of the packaging)	Market research	8-11-2022	1
1.4	R	When the packaging is sold online the design should be specifically made to withstand longer transportation times and rougher handling.	Since the branding on the packaging is not influenced that much. The packaging sould ensure the contents arive at the home undamaged at least 85% of the time.	Test by transporting the packaging through regular shipping.	Market research	8-11-2022	1
1.5	R	The secondary packaging must contain multiple primary packagings, minimum of 4 packaging.		Test by checking whether the secondary packaging exists out of multiple primary packages.	Market research	23-1-2023	2
1.6	R	The secondary packaging must be able to be stacked up to 5 boxes height.	It needs to be strong enough not to crush the other boxes and packaging.	Test by stacking and checking for damage.	Use and user research	11-11-2022	1
1.7	W	The secondary packaging must be reusable.	For at least 5 times	Test by trying to reuse the secondary packaging.	Market research	8-11-2022	1
1.8	R	The tertairy packaging must be able to hold at least 10 of boxes.	This account for 10 times the amount of packages in the secondary packaging.	Test by couting the amount of boxes	Market research	23-1-2023	2
1.9	W	The tertairy packaging must be reusable.	For example pallets, but also the wrapping used to fix the boxes on the pallet. For at least 5 times	Test by reusing tertairy packaging.	Market research	10-2-2023	1
1.10	R	The packaging should be able to be used by 80% of consumers.	In Europe.	Test by user testing	Market research	8-11-2022	1
1.11	W	The packaging must be inclusive to all who are colour blind and blind.		Test by user testing	Technology research	8-11-2022	1
1.12	R	Additional functionality must be added if there is something that could increase the usability/convenience of the product.		Test by checking whether another functionality has been created. Also perform user test to see whether they also recognise the extra functionality.	Use and user research	10-2-2023	2
1.13	R	The packaging should be able to hold a minimum of 375 grams of cereal.		Test by weighting the container with cereal.	Detailling phase	21-3-2023	1
1.14	R	The packaging should be able to hold a maximum of 1 kg of food contents.	Depending on the type of food that is inserted.	Test by weighting the container.	Use and user research	24-4-2023	2
1.15	R	The packaging should fit in a regular cabinet as well as in supermarket shelves.	Smallest cabinet has a depth of 19 cm and a height of 72 cm, and the depth of supermarket racks are 30 cm the heigth is adjustable.	Test by placing the packaging in shelves (at home and in the supermarket).	Ergonomics	8-11-2022	1
1.16	R	The packaging should be able to be held by 80% of consumers.	Population from Europe.	Test by user testing	Use and user research	8-11-2022	1
1.17	R	When the packaging is closed it must not spill the contents.		Test by filling packaging and trying to spill the contents.	Technology research	8-11-2022	1
1.18	R	The packaging should be able to be used by consumers over the age of 12.		Test by user testing	Use and user research	8-11-2022	1
1.19	R	The packaging should be able to be used to poor the food contents into a bowl or other dishes.	Without needing extra tools.	Test by trying to poor contents out of packaging. Also perform user testing to see whether they are also able to recognise the poor side and how to poor.	Technology research	8-11-2022	1
1.20	R	The packaging should be able to be stacked on top of each other.	At least two cans directly on top of each other. The boxes should also provide strenght for stacking them.	Test by stacking at least 2 cans on top of each other.	Technology research	8-11-2022	1
2. Technical requirements							
2.1	R	The reusable packaging must not cause any (minor) injuries.	These include small cuts and bruises.	Test by using skin like material and try to create cuts on the sharpest edges the packaging has.	Technology research	8-11-2022	1
2.2	R	The reusable packaging must not have any sharp edges.	To prevent injuries.	Test by checking all edges.	Technology research	11-11-2022	1
2.3	R	The primary packaging must survive a drop from 1 metre.	With no visible deformation on the primary packaging.	Test by performing drop tests.	Market research	8-11-2022	1
2.4	R	The secondary packaging must survive a drop from 1 metre.	With no visible deformation on the primary packaging.	Test by performing drop tests.	Market research	8-11-2022	1
2.5	W	The packaging should be able to be traced.	To ensure the packaging last for several reuse cycles.	Test by tracing packaging.	Use and user research	23-1-2023	2
2.6	R	The packaging must be able to survive temperatures up to 80 degrees for 10 minutes.		Test by placing packaging into washing machine and leaving it there for 10 minutes.	Technology research	8-11-2022	1
2.7	R	The packaging must be able to be washed with washing detergents and rinse aids.	Types are described in washing system research section.	Test by washing it with washing detergents and rinsing it.	Technology research	8-11-2022	1
2.8	R	After washing the contamininants must be removed.		Test by performing CFU test.	Technology research	8-11-2022	1
2.9	R	The packaging must be manufacturable.	By all types of existing production techniques	Test by checking possibilities.	Technology research	10-2-2023	1

2.10	W	The packaging should be able to be produced using DRD, DWI and 3P can manufacturing		Test by checking whether it can be produced using any of these techniques. Perform test-run.	Technology research	10-2-2023	2
2.11	R	The packaging should be either 2P or 3P cans	Unless there is another innovative packaging solution.	Test by looking at the amount of pieces the packaging exists from.	Technology research	11-11-2022	1
2.12	R	The production technique chosen must be able to be used by most of the can manufacturers.	9 out of 10 can manufacturers.	Test by going to manufacturers and see whether they are able to use the production technique chosen.	Technology research	8-11-2022	1
2.13	R	The production of the packaging should not damage the coating of Protact.	The dents or shapes should not be too deep as this might stretch the packaging to much, and tear the coating.	Test by checking the surface after it has been shaped.	Technology research	8-11-2022	1
2.14	R	The packaging must be produced using the least amount of material.	Also according to regulation.	Test by trying the same design with different thicknesses.	Technology research	8-11-2022	1
2.15	R	The packaging should not weight more than 200 g.		Test by weighing the empty packaging.	Use and user research	8-11-2022	1
2.16	R	The packaging should not be bigger than 190 mm x 400 mm x 720 mm.	Based on kitchen cabinet sizes.	Test by measuring the packaging.	Ergonomics	8-11-2022	1
2.17	R	The inside of the packaging must not corrode.	At least not before it has been washed.	Test by looking at the packaging after 1 week, 22 weeks and 52 weeks after production.	Technology research	23-1-2023	2
2.18	R	The edge of the packaging must not corrode.		Test by looking at the packaging after 1 week, 22 weeks and 52 weeks after production.	Technology research	23-1-2023	2
2.19	R	The outside of the packaging should not corrode.		Test by looking at the packaging after 1 week, 20 weeks and 52 weeks production.	Technology research	23-1-2023	2
2.20	R	The cap of the packaging should seal the packaging so that no air or water can get into the food.		Test by placing the packaging in air thight container and putting pressure on it.	Technology research	23-1-2023	2
2.21	R	The primary packaging must survive vibration up to 100 Hz frequency for 2 hours.	After this period there should be no visual damages on the packaging.	Test by creating the circumstances.	Technology research	21-3-2023	2
2.22	R	The packaging must widthstand forces up to 10 N from above.	The packaging need to be able to be stacked, this requires it to widthstand these forces.	Test by appling the forces to the container.	Technology research	23-1-2023	2
2.23	R	The packaging must survive forces up to 10 N from the side.	With food inside of the packaging.	Test by appling the forces to the container.	Technology research	23-1-2023	2
2.24	R	The packaging must survive forces up to 10 N from the side.	Witout food inside the packaging.	Test by appling the forces to the container.	Technology research	23-1-2023	2
2.25	R	The packaging must be able to be opened with a maximum of 9,8 N (1kg).	To ensure elderly can also open the packaging.	Test by measuring the amount of force needed to open the packaging.	Technology research	8-11-2022	1
2.26	R	The packaging must be strong enough to ensure no dents can appear under a force of 15 N.	This will ensure that the packaging is durable. As even the smallest dents could scare consumers away.	Test by drop tests.	Technology research	23-1-2023	2
2.27	W	The packaging must be able to survive temperatures up to 80 degrees for 2 hours.	For house washing of the packaging.	Test by placing packaging in domestic washing machine.	Technology research	8-11-2022	1
2.28	R	The cap of the packaging must be able to be opened and closed several times without damage.	Up to 100 times per ten cycles.	Test by opening and closing packaging.	Technology research	10-2-2023	1
3. Scenario requirements							
3.1	R	The packaging must survive exposure to moisture for at least 60 minutes.		Test by placing the packaging in a moist environment for 30 minutes.	Technology research	21-3-2023	2
3.2	R	The reusable packaging must show the consumers the benefits there are when reusing packaging.	This can also be shown on secondary packaging.	Test by checking whether there is any information available.	Market research	8-11-2022	1
3.3	R	The packaging and business plan must convince the consumer/brand owner/ retailer to start using the reusable packaging.	Must convince 70% of users.	Test by user survey.	Market research	10-2-2023	1
3.4	R	The reusable packaging must convince users to start reusing more often.	Must convince 7 out of 10 consumers.	Test by user survey.	Market research	8-11-2022	1
3.5	R	The refill for the reusable packaging should be available 95% of the time.		Test by checking availability of the refill regularly (can also be online stock checks).	Use and user research	8-11-2022	1
3.6	R	The packaging needs temper evidence.	To show to consumers that no body has touched the contents.	Test by checking is temper evidence is present.	Use and user research	8-11-2022	1
3.7	W	When the packaging is dented it should first be tried to mend it before recycling it.		Test by trying to de-dent the packaging and check whether it is possible to restore the packaging.	Market research	8-11-2022	1
3.8	R	The reusable packaging should be used in combination with a reuse model, defined by the Ellen MacArthur Foundation or Muranko et al.		Test by cheching whether one of those reuse systems have been used.	Market research	23-1-2023	2
3.9	R	The user should know how the reuse systems works within 5 minutes of looking at the packaging.	Packaging includes secondary in-store packaging.	Test by user testing.	Use and user research	8-11-2022	1
3.10	R	The reusable packaging must be easy to find, in a physical as well as online store.	There should be visible advertisement drawing consumers to it. For at least 7 out of 10 consumers.	Test by user testing.	Use and user research	8-11-2022	1
3.11	R	The reusable packaging must show the users were to return the packaging.	On the packaging as well as the secondary packaging.	Test by checking if information is present.	Use and user research	23-1-2023	2
3.12	R	In 95% of situations no unsafe situations might occur when using the reuse system or reusable packaging.		Test by testing possible dangerous situation.	Use and user research	8-11-2022	1
3.13	R	The design of the packaging must be easthetically pleasing for 75% of consumers		Test by user survey.	Use and user research	8-11-2022	1
3.14	R	The design of the packaging must look clean to 9 out of 10 consumers.		Test by user survey.	Use and user research	8-11-2022	1
3.15	R	The design of the packaging must look safe to 90% of consumers.		Test by user survey.	Use and user research	8-11-2022	1
3.16	R	The consumer should be able to use a spoon to remove the contents of the packaging without damaging the surface.		Test by checking whether it is possible to use a spoon.	Ergonomics	8-11-2022	1
3.17	R	The design of the packaging must show to 8 out of 10 consumers how to use the packaging.		Test by user testing.	Use and user research	8-11-2022	1
3.18	R	Th packaging should not be displayed/stored in a store above a height of 150 cm.	As this might cause dangers to childern or small people walking past the aisles.	Test by checking is the height of the shelve is not above the height.	Ergonomics	8-11-2022	1
3.19	R	The packaging should be able to be transported in a supermarkt carts without any visual damages.	With maximum shopping time of 45 minutes.	Test by recreating supermarket circumstances.	Technology research	23-1-2023	2
3.20	W	The packaging should show the consumers what food is stored inside of it.	Does not have to be transparent to show what it inside. A label could also be used.	Test by checking whether it is possible to see the contents or whether there is text listing what it inside of the packaging.	Use and user research	23-1-2023	2
3.21	R	8 out of 10 consumers should be able to clean the packaging at home.	In case the packaging is user owned.	Test by user testing.	Market research	8-11-2022	1
3.22	R	The packaging should be able to be held in one hand.	To ensure it is easier to bring the packaging to the store. This will increase the convenience.	Test by holding packaging in one hand for at least 10 minutes.	Use and user research	11-11-2022	1
3.23	R	The packaging should be clean when sold.	99% of bacteria should be killed.	Test by doing swab test.	Market research	10-2-2023	1
3.24	W	The design of the packaging should be made in a way that dents are not that visible.	Or so that the packaging has extra strength to make denting harder.	Test by comparing different design and see which one works best.	Use and user research	11-11-2022	1
4. Ecosystem & consumer requirements							
4.1	R	The price for the reusable packaging should not be more than 10% above the price of the single-use alternative.	Preferrably the price should be lower or maximum 5% (wish).	Test by comparing price of reusable packaging and single-use packaging.	Use and user research	11-11-2022	1
4.2	W	The price of the reusable packaging should be equal or less expensive than the single use packaging.		Test by comparing prices.	Use and user research	23-1-2023	2
4.3	R	The packaging must have a premium appareance.	So it is perceived as strong and a safe packaging.	Test by user testing.	Use and user research	10-2-2023	1
4.4	R	The reusable packaging should be durable and last for at least 1 year.	In case the packaging is user owned.	Test by tracing packaging and seeing whether it is used for 1 year.	Use and user research	8-11-2022	1
4.5	R	The reuse system should be available in a radius of 10 km around the consumers' home.		Test by going to random locations and checking whether there are reuse systems within 10 km.	Use and user research	8-11-2022	1
4.6	R	The reuse return system should be available in local supermarkets.	In bigger as well as smaller cities.	Test by asking supermarkets whether they provide return points.	Use and user research	8-11-2022	1
4.7	R	Before purchasing the reusable packaging the consumer should be informed about the manner in which the packaging is cleaned.	To ensure that the hygienic issue is not going to be a problem.	Test by checking whether information is provided in the store or online.	Use and user research	23-1-2023	2
4.8	R	The consumer should be informed about the environmental issues. By means of local news or advertising from big brands.	To ensure that more consumers would be willing to reuse packaging.	Test by user survey before and after advertising need for more sustainable packaging.	Use and user research	8-11-2022	1
4.9	R	The reuse system used should ensure that the least amount of changes are required from the business.	So businesses are more likely to coorporate.	Test by listing the changes required and try to minimize these.	Use and user research	8-11-2022	1
4.10	W	The reuse system used should require the least amount of effort from the consumer, to increase the convenience.		Test by user testing.	Use and user research	11-11-2022	1
4.11	R	The reusable packaging should adhere to the brand image.	8 out of 10 consumers should recognise the brand of the reusable packaging.	Test by user survey.	Use and user research	8-11-2022	1
4.12	W	The reusable packaging should be able to be used by several brands, with different advertising for example.	This would be better for the environment.	Test by checking the packaging can be used by several brands.	Use and user research	23-1-2023	2
4.13	R	After the packaging is emptied and returned the packaging should be able to be stacked together, to safe space.	Without creating visual damage to the packaging.	Test by stacking the packaging together and look for visual damage.	Use and user research	23-1-2023	2
4.14	R	The packaging should survive at least 10 reuse cycles.	Reuse cycle: Filling - Display - Buying product - Using product - Returning product - Cleaning	Test by letting the packaging go through 10 reuse cycles.	Loop introduction	8-11-2022	1
4.15	R	At the end of life of the packaging, the packaging should be recyclable.		Test by checking whether the packaging is recycled properly.	Loop introduction/ market research	8-11-2022	1
4.16	R	After cleaning the packaging no bactaria can be left on the surface.		Test by performing CFU test.	Technology research	8-11-2022	1
4.17	R	When using a refill system the hygiene of the reuse system should be the top priority.		Test by checking priorities.	Use and user research	23-1-2023	2
4.18	R	When a refill system is used cleaning the system should be made as easy as possible.		Test by checking several options and comparing them.	Use and user research	11-11-2022	1
4.19	R	The material costs should be as low as possible.		Test by checking alternatives and calculating prices, and strenghts.	Use and user research	23-1-2023	2
4.20	R	The business plan should ensure that all stakeholders gain a positive benefit from collaborating for reusable packaging.	This will ensure that the succes chance will become higher.	Test by checking business plan.	Use and user research	23-1-2023	2
4.21	R	When investments are needed from stakeholders, ensure they would be able to have their return on investment within 5 years.		Test by calculation and estimating sales	Use and user research	23-1-2023	2
5. Material requirements							
5.1	R	The material used for the primary packaging must be Protact.	The composition of Protact is not fixed yet. It is not limited to using Protact only it can be combined with other materials.	Test by checking the material.	Introduction Protact	11-11-2022	1
5.2	R	The material must be scratchresistant.	Up to 1 kg of force.	Test by performing scratchresistance test.	Material research	23-1-2023	3
5.3	R	The coating of the material should be intact after 10 reuse cycles.	No scratches that penerate the coating.	Test by checking coating after 10 cycles.	Material research	11-11-2022	1
5.4	R	The material must survive at least 5 amount of drop of 0.5m height, or 2 times 1m drop or 1 time 1.5m drop.	Considering the packaging falls 1 times during two cycles.	Test by performing drop tests.	Material research	23-1-2023	2
5.5	R	The packaging must not damage another packaging when they are placed close to each other.		Test by performing vibration tests.	Material research	11-11-2022	1
5.6	R	The material must be strong enough to survive a drop from 1 meter without any visual damage.	With filled and empty packaging	Test by droptesting.	Material research	11-11-2022	1
5.7	R	The packaging must use the least amount of different types of material as necessary.	If different materials are used ensure they are able to be seperated before recycling.	Test by checking types of material used.	Material research	23-1-2023	2

5.8	R	as strong as possible.		Test by checking alternative options and comparing them.	Material research	11-11-2022	1
5.9	R	After washing with washing detergents the adhesion of the coating of Protact should not have changed.		Test by checking adhesion.	Material research	23-1-2023	2
5.10	R	The material should survive 30 minutes at a temperature of 80 degrees.		Test by placing packaging in heated room.	Material research	23-1-2023	2
5.11	R	The material should survive 20 minutes in water at a temperature of maximum 70 degrees.		Test by placing packaging in heated water.	Material research	23-1-2023	2
5.12	W	The packaging should not damage each other when being dropped in the return bag.	When dropped into bag they can damage each other, keep this at a minimum.	Test by recreating circumstances and checking the damage.	Material research	23-1-2023	2
5.13	R	The compostion of the material should not change during the heating, using and returning of the packaging.		Test by recreating cycles and checking for damage.	Material research	23-1-2023	2
5.14	R	The outside of Protact used should be made out of PET or PP.		Test by checking material.	Material research	11-11-2022	1
5.15	R	The inside of Protact used should be made out of PET or PP.		Test by checking material.	Material research	11-11-2022	1
5.16	R	The outside coating of protact should be 40 um.	This is the regular thickness of the coating layer.	Test by measuring thickness.	Material research	23-1-2023	2
5.17	R	The inside coating of protact should be 40 um.	This is the regular thickness of the coating layer.	Test by measuring thickness.	Material research	23-1-2023	2
5.18	R	The substrate needs to be 0.25 mm thick.	In order to survive drops from 1 metre.	Test by measuring thickness of substrate.	Material research	21-3-2023	2
5.19	R	The coating should contain the least amount of airbubbles possible.	As this might cause holes later in the process.	Test by measuring air bubbles.	Material research	23-1-2023	2
5.20	R	The quality of the coating for the reusable packaging should be premium, there should be no holes, scratches.	To ensure the coating will last as long as possible.	Test by checking the quality.	Material research	23-1-2023	2
5.21	R	The washing system should not go over temperatures of 90 degress.	From this point PET will become more loose, and edges might come off.	Test by checking washing temperatures.	Material research	23-1-2023	2
5.22	R	The bottom of the packaging should be reinforced.	This is the point were most damage occurs when dropped.	Test by checking thickness of bottom can.	Material research	23-1-2023	2

6. Legislation requirements							
6.1	R	By the end of 2024, product responsibility schemes must be established for all packaging.	According to directive (EU) 94/62/EC	Test by checking whether the producer is held accountable for the packaging produced.	Technology research	8-11-2022	1
6.2	R	According to regulation (EU) No 1169/2011 all food packaging must be provided with the following information; food's name, list of ingredients, net quantity, use-by-date, instruction for use, operator's name and address and nutrition declaration.		Test by checking information on the packaging.	Technology research	8-11-2022	1
6.3	R	The information on the packaging must not mislead consumers.	According to regulation (EU) No 1169/2011.	Test by checking information on the packaging.	Technology research	8-11-2022	1
6.4	R	Materials in contact with food must not release their contents into food at levels that are harmfull to human health.	According to regulation (EU) No 1935/2004.	Test by performing spectroscopie tests.	Technology research	8-11-2022	1
6.5	R	Materials must not change the composition of food, taste and odour in an unacceptable way.	According to regulation (EU) No 1935/2004.	Test by performing spectroscopie tests.	Technology research	8-11-2022	1
6.6	R	The characteretics of reusable packaging must make it suitable for reuse.	According to directive (EU) 94/62/EC	Test by checking charecterestics.	Technology research	8-11-2022	1
6.7	R	The packaging should be produced in compliance with labour regulations.	According to directive (EU) 94/62/EC	Test by checking labour circumstances.	Technology research	8-11-2022	1
6.8	R	The amount of waste of packaging must be decreased. By means of deposit schemes, economic incentives and minimum recycling rates for each packaging type.	According to directive (EU) 2008/98/EC	Test by checking whether the packaging uses a scheme to decrease the material waste.	Technology research	8-11-2022	1
6.9	R	Printing inks used on packaging must not tranfer to the food contact side of the packaging.	According to regulation (EU) No 2023/2006	Test by performing spectroscopie tests.	Technology research	8-11-2022	1
6.10	R	The printed surface of the packaging must not come in direct contact with food.	According to regulation (EU) No 2023/2006	Test by checking whether inkt side does not come in contact with food.	Technology research	8-11-2022	1
6.11	R	The packaging must adhere to directive (EU) No 2018/852.		Test by checking regulation.	Technology research	8-11-2022	1
6.12	R	The packaging must adhere to regulation (EU) No 2018/775.		Test by checking regulation.	Technology research	8-11-2022	1
6.13	R	The packaging must adhere to regulation (EU) No 2022/0396 (COD)		Test by checking regulation.	Technology research	23-1-2023	2

7. Tata Steel requirements							
7.1	R	The packaging should be able to be used by Tata Steel to demonstrate to brand owners what the possibilities are of Protact.		Test by checking whether packaging is used to demonstrate possibilities	Introduction Tata Steel	8-11-2022	1
7.2	W	The packaging should be designed for the food industry.	If this is not possible another industry may be chosen as well.	Test by checking whether packaging is used in food industry.	Introduction Tata Steel	8-11-2022	1

Appendix U: Mindmaps

In this appendix the mindmaps of the aspects transportation, hygiene, convenience and corrosion edges can be found.

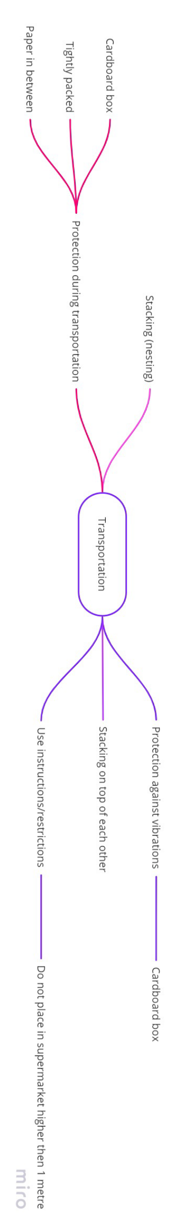


Figure 113: Mindmap transportation

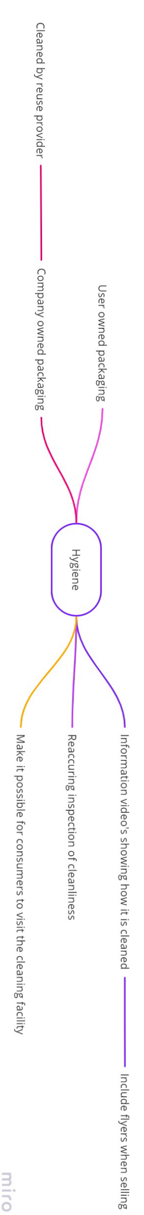


Figure 114: Mindmap hygiene

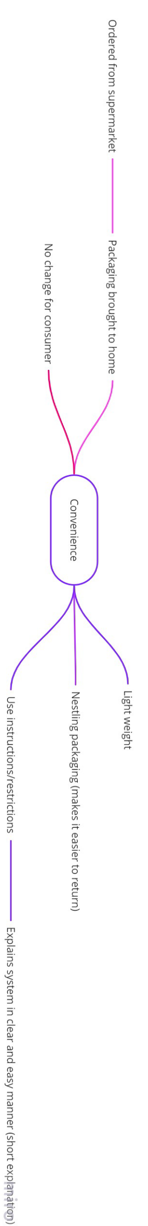


Figure 115: Mindmap convenience

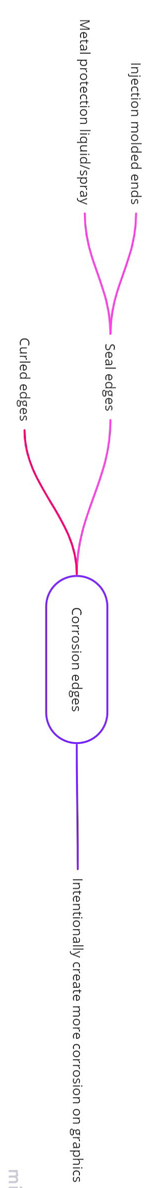


Figure 116: Mindmap corrosion edges

Appendix V: Brainstorm plan

The brainstorm will be performed to determine important aspects regarding reusable packaging (or add more if they are already known).

Main question brainstorm:
How do we ensure the reusable packaging can be used for as long as possible, with a high convenience for the consumer?

What are the attention points when developing a reusable packaging?

Reusable packaging
First it is important to see which aspects they would come up with before giving them options. This might lead to new insights. If there are no new insights continue with what you have got. (+- 5 min)

What aspects should I take into consideration when designing reusable packaging?

Possible aspects:
- Strenght of packaging / Denting / Weight
- Scratching
- Transportation
- Hygiene
- Convenience/User experience
- Closures (how do you close the packaging)
- Corrosion at the edges

Go through each aspect and come up with ideas that could enhace this specific aspect. (+- 20 min)

Possible questions, related to the aspects:
- What could increase the customer experience using a reusable packaging? (increasing convenienc etc)
- Ergnomony?
- What are the options for hiding dents/scratches for reusable packaging (to ensure the lifetime of the packaging increases)
- What options are there to decrease the weight of the packaging?
- What options are there to mend dented packaging?
- What options are there to close the packaging, as being able to reclose the packaging?

Appendix W: Brainstorm images marketing team and R&D team

On the following pages images taken during the brainstorm can be found. To show an impression of what the brainstorm looked like.

Figure 117 till 120 show an impression of the R&D brainstorm.


Figure 117: R&D brainstorm 1/4


Figure 118: R&D brainstorm 2/4


Figure 119: R&D brainstorm 3/4


Figure 120: R&D brainstorm 4/4

Figures 121 till 123 show an impression of the brainstorm with marketing.


Figure 121: Marketing brainstorm 1/3


Figure 122: Marketing brainstorm 2/3


Figure 123: Marketing brainstorm 3/3

Appendix X: Idea sketching

In this appendix the full images of the sketches can be found. The following figures show the sketch pages, figure 124 till 130.

Figure 124: Sketches convenience

Figure 125: Sketches Image of packaging

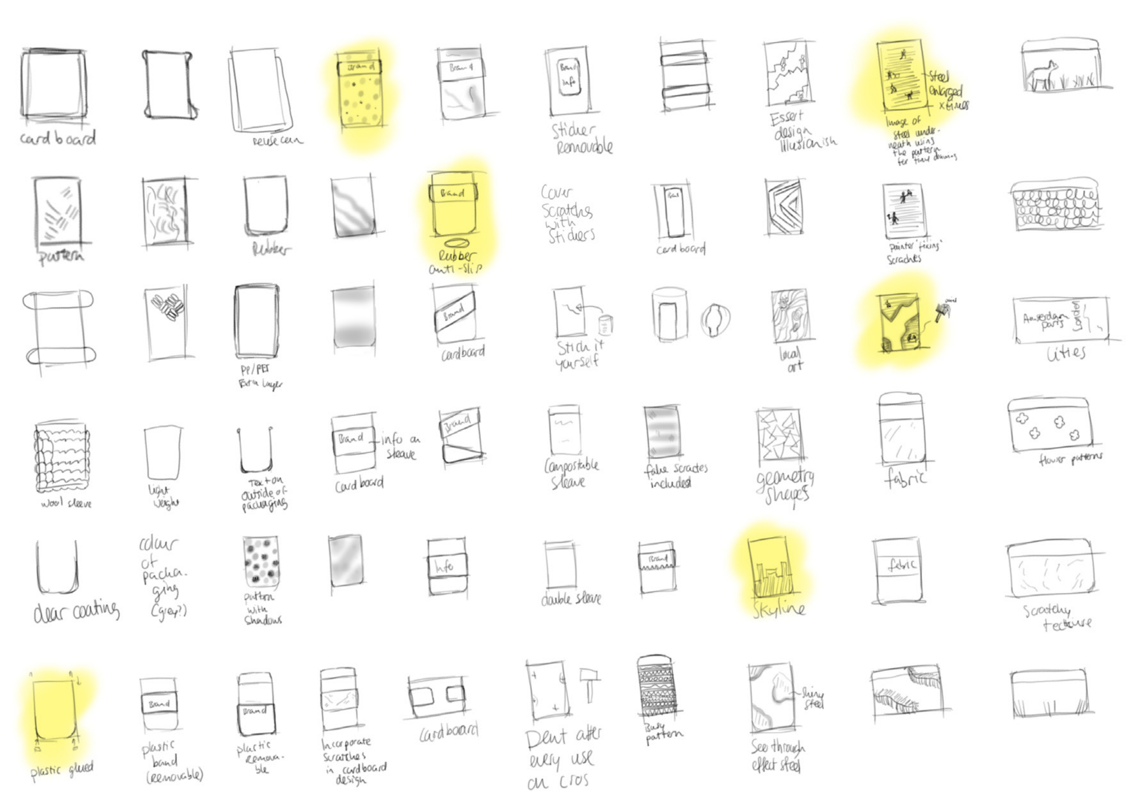


Figure 127: Sketches scratching

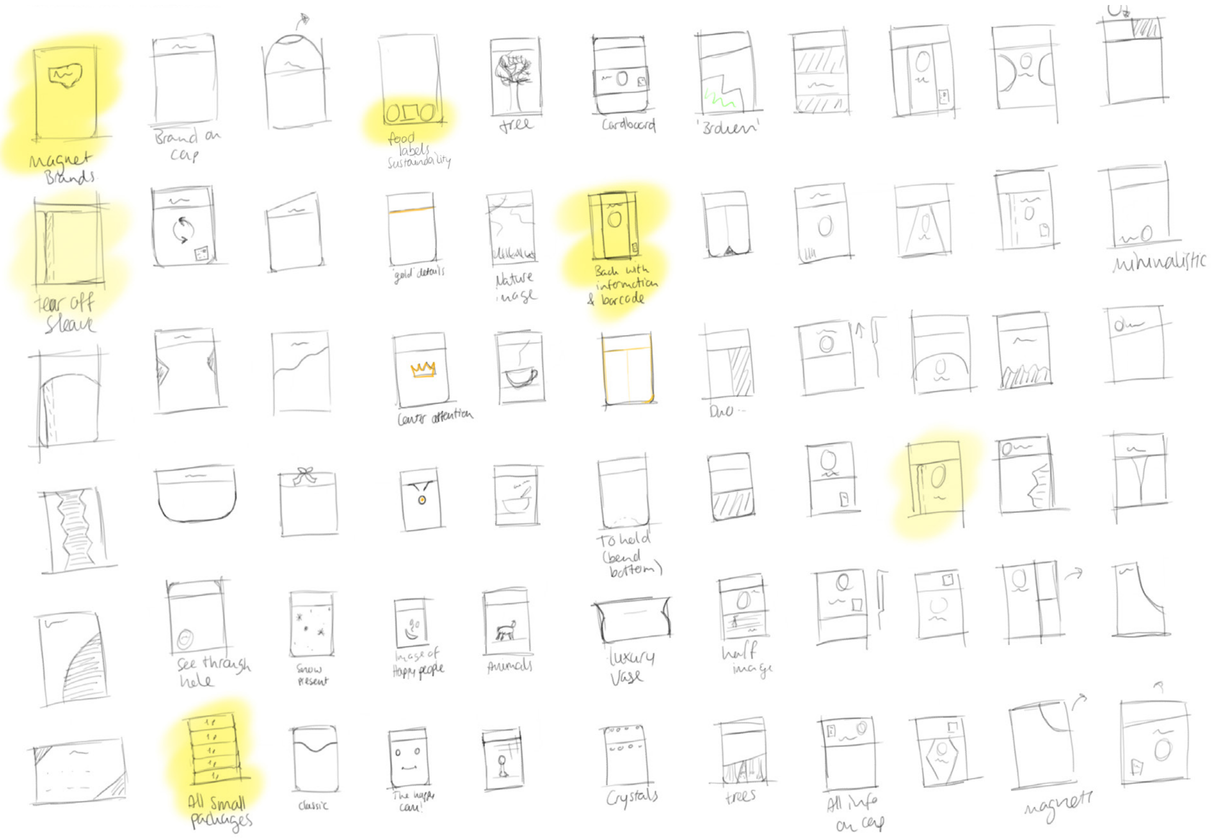


Figure 126: Sketches image of packaging 2

Figure 128: Sketches strenght of packaging

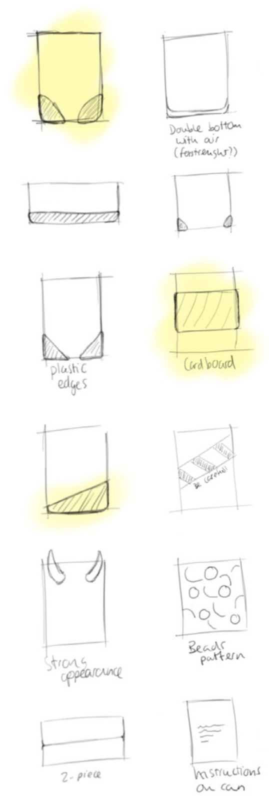


Figure 129: Sketches strenght of packaging 2

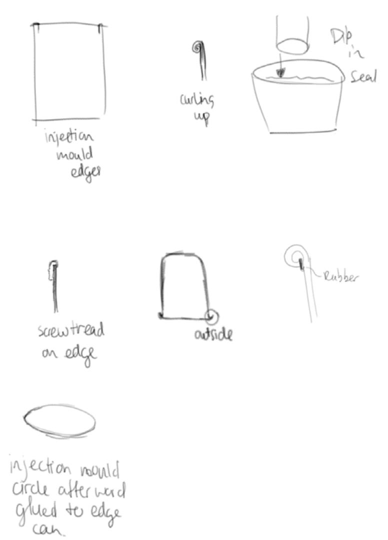


Figure 130: Sketches corrosion edges

Appendix Y: Concept choice

The first section of this appendix is the scoring table, and the second section contains the survey results.

Scoring table

The scoring table can be found in table 6. Each essential requirement or aspect has been assigned a value in this table. The value assigned to each concept will be multiplied by the points generated for each concept. Thus, the most important aspect will be given a greater weight than the less important ones. The possible range of points per factor is between 1 and 5. The values generated are the result of research and brainstorming sessions.

Table 6: Scoring table concept choice

Nmb.	Requirement/aspect	Value	Concept 1	Concept 2	Concept 3	Concept 4
4.19	The material costs should be as low as possible. (costs)	3	12	9	9	12
1.22	The packaging should be able to be stacked on top of each other. (logistics)	1	4	4	4	3
3.23	The packaging should be clean when sold. (hygiene)	3	12	12	12	12
2.9	The packaging must be manufactu-rable. (Manufacturability)	2	10	6	8	4
3.3	The packaging and business plan must convince the consumer/brand owner/ retailer to start using the reusable packaging. (convincing consumer/brand owner/retailer)	2	4	6	8	8
5.8 (3.24)	The packaging must use the least amount of material necessary while still being as strong as possible. Or must have a camouflaging appea-rance. (strength)	3	9	12	12	9
4.3	The packaging must have a premi-um appearance. (image of pack-aging)	1	3	4	4	3
5.2	The material must be scratch re-sistant. (scratching)	3	9	9	15	12
1.15	Additional functionality must be ad-ded if there is something that could increase the usability/convenience of the product. (Convenience)	3	6	15	12	9
2.28	The cap of the packaging must be able to be opened and closed sever-al times without damage. (closures)	2	6	6	8	6
2.18	The edge of the packaging must not corrode. (corrosion edge)	3	9	12	12	12
Total score			84	95	105	90

The scoring table reveals that concept 3 has the most points, with concept 2 following closely behind. Concept 3 has the most points due to its ability to conceal scratches and dents, its manufacturing simplicity, and its transparent cap. Concept 1 and 4 has received the fewest points. Concept 1 is ineffective at concealing scratches and offers no additional functionality to the consumer. Concept 4 is space-efficient, but this packaging cannot be created using the 2P manufacturing method. Concept 2 has an interesting method for concealing scratches and employs an easy pour, which would increase the product's usability but decrease its manufacturability slightly. This scoring table's information will be compared to the results of the concept selection survey.

Concept choice survey

81 Tata Steel employees have responded to the survey regarding concept choice. Due to the sensitivity of the information, the survey was not distributed externally. The results will be presented using numbers and pie charts. At the beginning of the survey, respondents were given information about the project and the four concepts. After which they were given questions about the four concepts.

They were asked to rate the concepts on a scale ranging from 1 to 5 in the first few questions. This has resulted in the following outcomes:

Concept 1 – Blue, has an average of 3,22
Concept 2 – Green, has an average of 3,38
Concept 3 – Yellow, has an average of 3,48
Concept 4 – Blue, has an average of 3,46

The following inquiry required determining which concept appeals to them the most. However, something went wrong with the survey, the questions was accidentally removed from the Dutch version of the survey. Only the English version retained this question, and seven colleagues responded to the English version. Only concept 2 received one vote, while the other concepts received two votes each. Due to the technical error, this question and answers will not be used.

The previous question was followed by a request for the least appealing concept. The answers are displayed in figure 131.

Additionally, it was asked which concept would be the most marketable. To determine if there is a significant difference between these answers. In figure 132, the results are displayed.

In addition, respondents were asked which option would be the least marketable. These outcomes are depicted in figure 133.

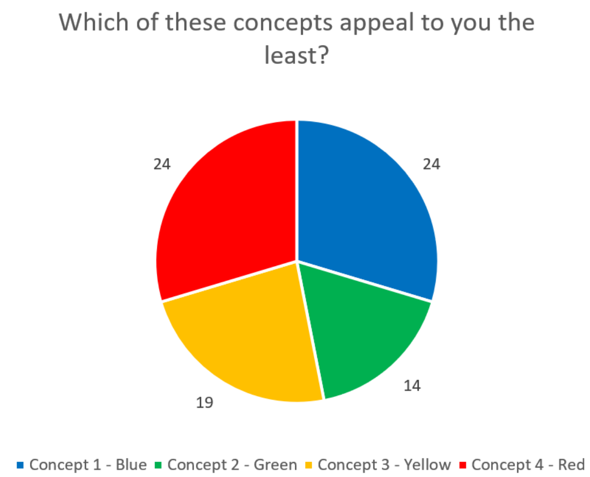


Figure 131: Results which of these concepts appeal to you the least?

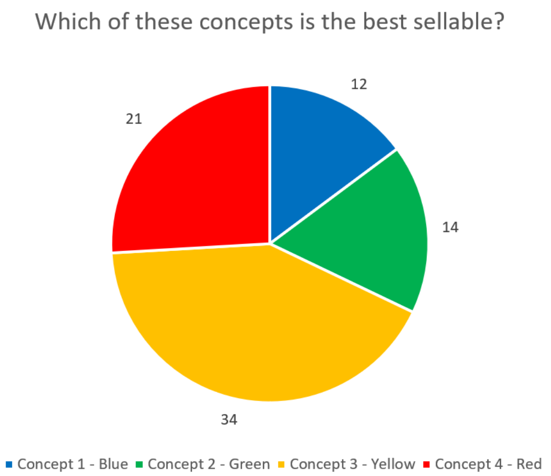


Figure 132: Results which of these concept is the best sellable?

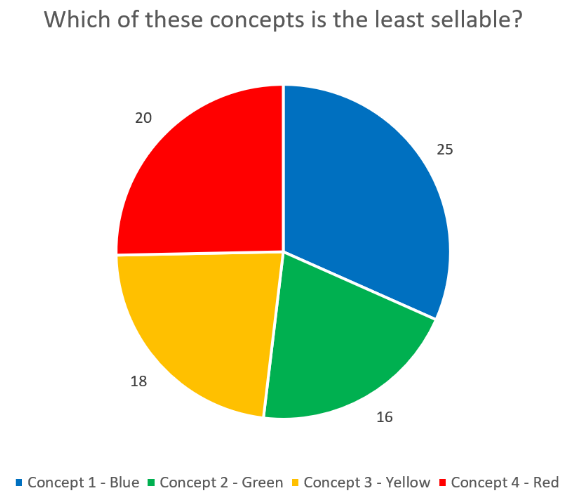


Figure 133: Results which of these concepts is the least sellable?

The following question asked which concept they chose to elaborate on. To discover what they would choose. The results are depicted in figure 134.

This question was followed by a request for specific elements that respondents would like to see incorporated into their preferred concept. For this, the responses were separated based on the option they selected in the previous question. It must be noted that this question was optional, so n in this instance was not 81.

For respondents who selected concept 1, the most frequently mentioned characteristics were a transparent cap and a screw thread.

Transparent cap and easy pour were cited most frequently by respondents who selected concept 2, with snap fit a close third.

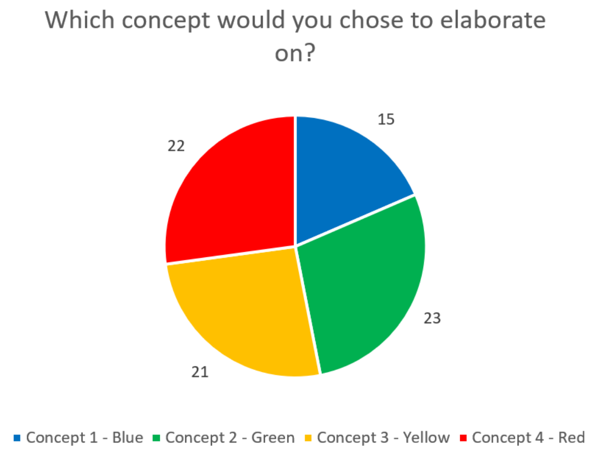


Figure 134: Results which concept would you chose to elaborate on?

For respondents who selected concept 3, the most frequently mentioned feature was easy pour.

Transparent cap, sleeve, and tracing were the most popular names aspects among respondents who selected concept 4. Also a few easy pours.

In table 7, the number of times each aspect was mentioned was added together to determine which aspect is most frequently mentioned. It can be seen from this table that easy pour and transparent cap were mentioned significantly more than the other aspects; these should be considered when choosing the final design.

Table 7: Scoring table concept choice

Aspects	Amount
No tracing	1
Easy pour	10
Square	4
Transparent cap	13
Sleeve	4
Screwthread	5
Magnetic label	6
Tracing (RFID, barcode)	6
Anti slip	2
Snap fit	4
Customizable cap	2

Appendix Z: Size of packaging

To determine the size of the packaging, it was necessary to determine the volume of each cereal variety. The decision was made to only elaborate on breakfast cereal to be more focused on one subject. For this research, four types of cereal were measured: Quaker Cruesli Luchtig, Quaker Cruesli Balans, Kellogg's Smacks, and Quaker Havermout. To determine the volume, a square box with known dimensions was used (by measuring them). With this information, the volume of the food could be calculated based on its height per 100 grammes. Figure 135 illustrates the measurement setup.

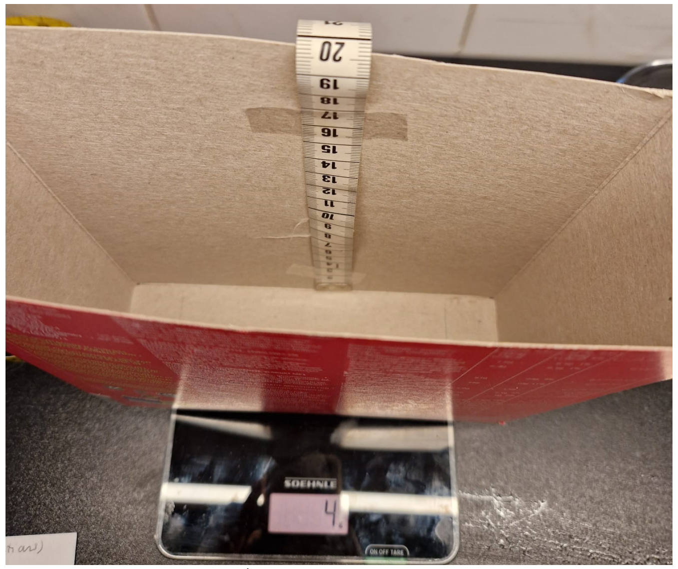


Figure 135: Setup volume measurements

The results of the measurement are shown in figure 136 till 139.

These measurements indicate that the volume of cruesli differs. Each box is 375 grammes in weight, but the volume varies considerably. In addition, the percentage of the box that was filled with contents was determined. Quaker Cruesli Luchtig and Balans combined to fill 54 percent of the sold box. While the Kellogg's Smacks box was filled to 63% capacity. The havermout box was filled to 74% capacity. The Havermout box did not contain a plastic bag, which could explain the higher percentage of volume filled.

The volume required for the packaging to hold equal quantities of cereal is approximately 1240 cm3; this is the mean of four measurements taken. Actual measurements taken with the 3D models are detailed in the appendix that follows. The height was measured after shaking the box slightly to disperse the hill inside. Due to the fact that the height was measured at the highest point, these measurements may contain a slight error.

Quaker Cruesli Luchtig		
		LxBxH (cm3)
Content box		1584
	100	228
	200	456
	300	684
	375	855

Figure 136: Volume measurement Quaker Cruesli Luchtig

Quaker Cruesli Balans		
		LxBxH (cm3)
Content box		2100
	100	342
	200	684
	300	912
	375	1140

Figure 137: Volume measurement Quaker Cruesli Balans

Kellogs Smacks		
		LxBxH (cm3)
Content box (g)		3420
	100	684
	200	1254
	300	1710
	375	2166

Figure 138: Volume measurement Kellog's Smacks

Quaker Havermout		
		LxBxH (cm3)
Content box (g)		1080
	100	228
	200	399
	300	627
	375	798

Figure 139: Volume measurement Quaker Havermout

Ergonomics hand

Research was conducted for the purpose of determining the optimal width of the grip. However, specific data that could be utilised for this project was lacking. As the packaging is not a handle requiring considerable force. Additionally, the food packaging will not be very heavy, nor will it be used for several hours at a time; it will likely be used for only a few minutes each day.

DINED [A11], a database created by TU Delft, was utilised to determine the grip along with other databases. This database contains circumference information for hand grips. The calculated dimensions are displayed in figure 140.

populations	Dutch adults 20–30, female		Dutch adults 20–30, male	
measures	mean	sd	mean	sd
Grip circumference (mm)	122	9	135	13

Figure 140: DINED database grip circumference

DINED only provided information for adults aged 20 to 30. Additionally, the circumference shows the length to which the fingers can extend. Calculating this into diameter, the average for females is 3.8 cm and the average for males is 4.3 cm. This is the maximum diameter that can be reached with the fingers and thumb joined. These findings are consistent with those of another study [A12]. Which stated that the maximum diameter of a cylindrical handle should be between 30 and 45 mm.

The information provided by these two sources will be used to calculate the maximum diameter that is possible. Figure 141 illustrates a Solidworks sketch in which the circumference of 122 represents half of the circle. Simulating the diameter when the fingers reach the middle of the circumference.

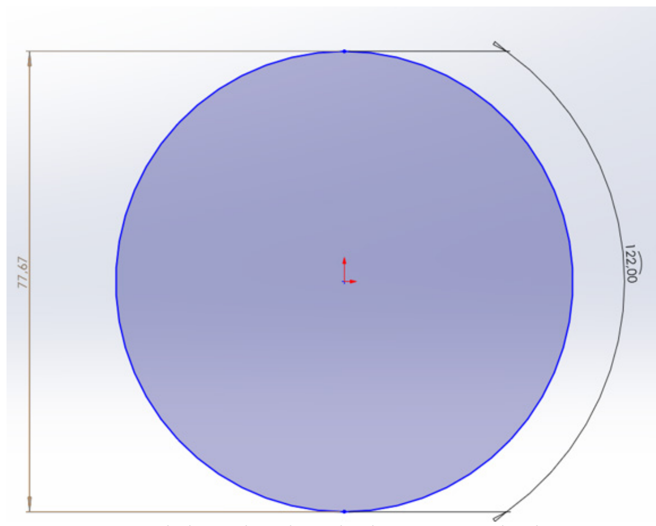


Figure 141: SolidWorks sketch diameter calculation

The diameter would be roughly 78 mm for females and 89 mm for males. These figures can serve as a guide for future design development. It is also possible to use a larger number, but for the time being, these are the recommended measurements. In addition to the product's material and rate of usage, the product's dimensions should be adjusted based on its characteristics. Given that the packaging is expected to be utilised for no more than a few minutes, the diameter could be increased. However, research should be conducted to determine if a larger diameter grip would be acceptable.

In addition to the maximum diameter allowed, it is essential to consider the maximum force allowed to open the packaging. In this instance, the packaging is opened with a snap-fit cap, so less force is required than with a standard screw thread. According to research, circular and elliptical shapes have different maximum twisting forces. The maximum force for circular is roughly 8 nm and for elliptic it is 10 nm. The pinch force will also be considered because the packaging requires pulling force to remove the snap-fit cap. The maximum pinch force is 4 kg (9 lb) [A13], and the force necessary to remove the cap must not exceed this value.

Cabinet measurements

In addition to ergonomics, a number of other measurements must be taken into account. These are the measurements of the cabinets and supermarket shelves. As they will require cabinet storage space. According to research [2,3], the depth of the cabinets varies between 19 and 50 centimetres. The average supermarket shelf height is 30 cm [1]. Cabinets and supermarket shelves can vary in height. Since the height is adjustable.

Appendix AA: Easy pour research

This appendix contains the research of easy pour. Four versions were compared to determine the most effective type of easy pour. To compare the results, a pour without easy pour was also applied. The following images depict the pouring zones of each easy pour variant. The zones have been separated into light and dark sections. The darker zone is where food falls most frequently, whereas the lighter zone is where food falls infrequently.

Figure 142 depicts the four types of easy-pour variation.

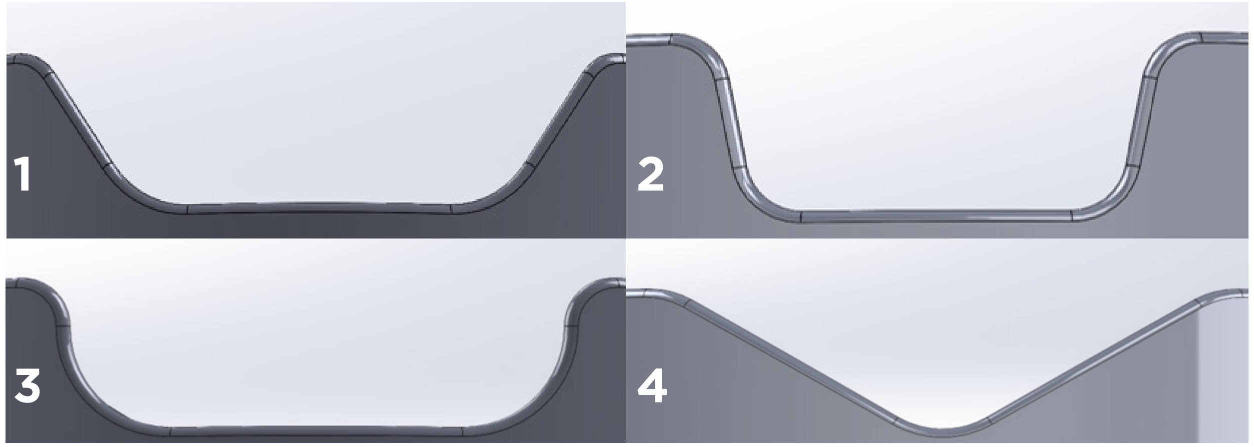


Figure 142: Easy pour 1,2,3 and 4

Cruesli Luchtig

Following are images that were captured during the recording of pouring. This recording is available by request. Figures 143, 144, 145,146, and 147 depict the pouring zones captured during the recording.

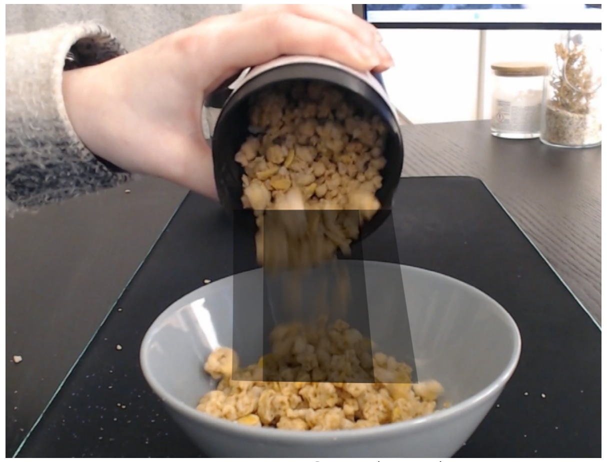


Figure 143: No easy pour Cruesli Luchtig


Figure 144: Easy pour 1 Cruesli Luchtig

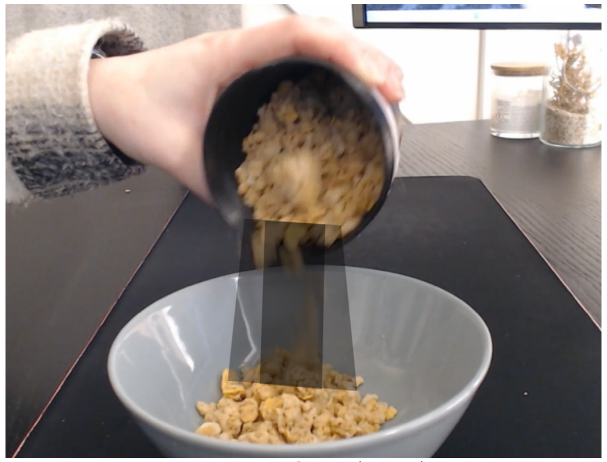


Figure 145: Easy pour 2 Cruesli Luchtig


Figure 146: Easy pour 3 Cruesli Luchtig


Figure 147: Easy pour 4 Cruesli Luchtig

Cruesli Balans

The following figures depict a frame of pouring Cruesli Balans: figures 148, 149, 150, 151and 152. The figures also show the pouring zones, in the same way they are depicted in the previous couple of figures.


Figure 148: No easy pour Cruesli Balans


Figure 149: Easy pour 1 Cruesli Balans


Figure 150: Easy pour 2 Cruesli Balans

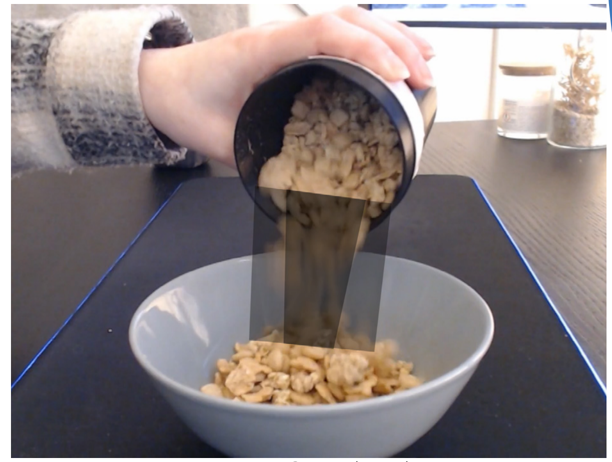


Figure 151: Easy pour 3 Cruesli Balans


Figure 152: Easy pour 4 Cruesli Balans

Havermout

The following figures depict frames of Havermout pouring, also from Cruesli. Figures 153, 154, 155, 156 and 157 depict the pouring zones observed during the recordings.

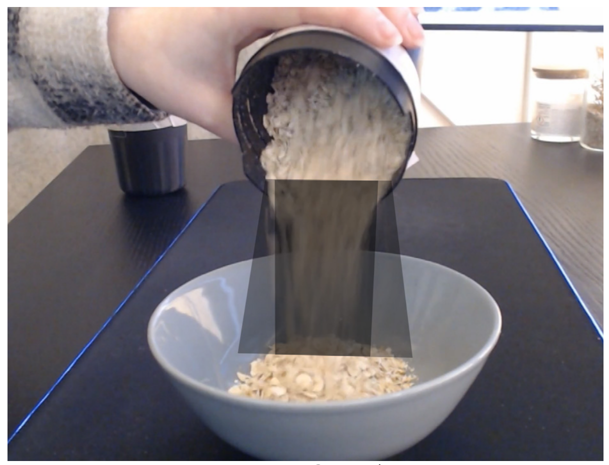


Figure 153: No easy pour Cruesli Havermout

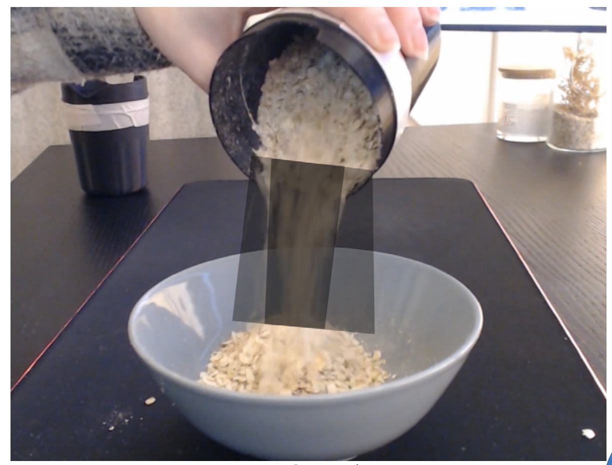


Figure 154: Easy pour 1 Cruesli Havermout

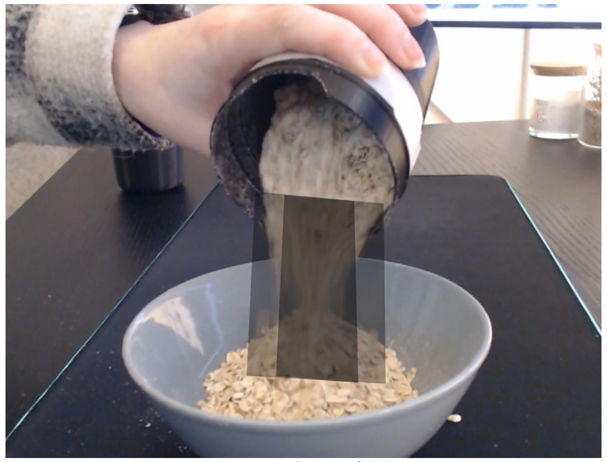


Figure 155: Easy pour 2 Cruesli Havermout

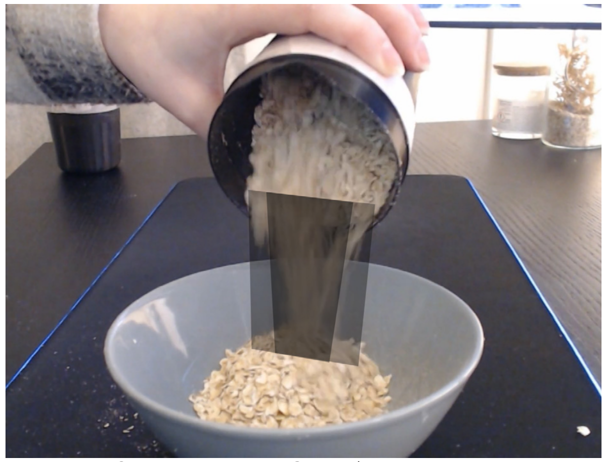


Figure 156: Easy pour 3 Cruesli Havermout

Figure 157: Easy pour 4 Cruesli Havermout

These figures depict the identical image as the other type of cereal. There is a distinct distinction between with and without easy pour. The pouring width has reduced considerably, particularly with easy pour variation 3.

Kellog's Smacks

The following figures depict a frame of pouring Kellogg's Smacks: 158, 159, 160, 161 and 162. These graphs also illustrate the pouring zones.

Figure 158: No easy pour Kellog's Smacks

Figure 159: Easy pour 1 Kellog's Smacks

Figure 160: Easy pour 2 Kellog's Smacks

Figure 161: Easy pour 3 Kellog's Smacks

Figure 162: Easy pour 4 Kellog's Smacks

Coffee beans

Coffee beans were the final food type used to test the easy pour. Figures 163,164, 165, 166, and 167 depict the pouring of coffee beans. These images also illustrate the pouring zones.

Figure 163: No easy pour coffee beans

Figure 164: Easy pour 1 coffee beans

Figure 165: Easy pour 2 coffee beans

Figure 166: Easy pour 3 coffee beans

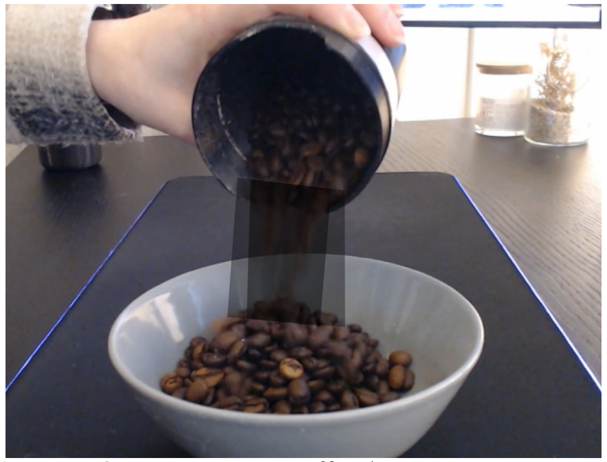


Figure 167: Easy pour 4 coffee beans

There was a noticeable difference between the non-easy pour and easy pour designs for pouring all types of food. The no-easy pour resulted in a wider pour width and a less controlled pour, as shown by the larger lighter zone in the images. Due to their narrower pour width, easy pour versions 2 and 3 generated the thinnest pours. Despite having a narrower width than the non-easy pour version, these versions were unable to prevent food from overflowing over the edges outside of the easy pour section when pouring larger.

Version 4 of the easy pour design, which employs a triangular shape with rounded edges, produced the widest pour, despite being narrower than the standard design. As demonstrated by the figures, the final recommended design would be based on easy pour version 3, which is sufficiently wide for the majority of food types and guides food more effectively than other designs. Additionally, this design features straighter edges to direct more food to the centre.

Appendix AB: Sleeve attachment

There are numerous attachment options for sleeves. One of the most obvious possibilities is glue. A variety of adhesives can be used to attach the solid board sleeve to the PP coating. For the sleeve to be easily detachable, however, such a glue must be completely water-soluble. Human interaction with the packaging to remove the sleeve is not preferred. Nonetheless, a few viable glue options remained; these will be discussed next.

EVA glue is a powerful adhesive that can join solid board to PP. In addition, it is utilised extensively in the packaging industry. These, specifically the hot melt variety, are used to glue the secondary boxes. There are water-soluble EVA glue varieties [4,5]. It is not specified, however, how long the EVA glue must dissolve before it is completely dissolved. It does state that after decomposition they are harmless, as they produce only carbon dioxide and water in most environments.

PVA glue was also of interest, as it is frequently used in craft projects [6]. With components such as wood, paper, leather, and cardboard. This adhesive is weaker than the one described previously. Additionally, this type of adhesive is water-soluble. However, approximately ten minutes are required to dissolve the glue [7]. In addition, undesirable manual labour is required to completely remove the adhesive.

In addition to these options, there are biodegradable adhesives made from cornflour, wheat, and potatoes. However, these types prohibit the attachment of solid board to PP. Consequently, alternatives to glue were required for this application. Physically preventing the sleeve from falling off is another means of achieving this goal. This was accomplished by using side embossing's and adding holes to the sleeve. Figure 168 illustrates the use of embossing on the packaging's exterior to prevent the sleeve from slipping down. This embossing can also be used to facilitate the nesting of packaging by positioning it in a location that prevents the packaging from collapsing completely and permits air to pass through.

Figure 168: Embossing for sleeve attachment

Appendix AC: Nesting progress

In order to prevent the packaging's from sticking together when nested, there must be air between the packaging's. Consequently, when they are separated, this air will provide the separation mechanism. As depicted in figure 169, the first feature added to the packaging to make this possible was an indentation in the packaging's base.

Figure 169: Embossing for sleeve attachment

Since this indentation alone would not be sufficient to prevent packaging from sticking together, a second characteristic was necessary. Because of this, a bend was added to the top. To prevent the packaging from completely collapsing, as shown in figure 170. Nevertheless, the location of the bend determines whether or not the packaging can still adhere. Because the top edge of the packaging is flexible, the manner in which it is nested within the image may cause it to still stick to each other. This is due to the fact that the material used is steel, which has a small amount of flexibility.

Figure 170: Upper bend

Several packaging's were investigated to determine how other packaging addressed this issue. Figure 171 illustrates the packaging used for analysis. All of these packaging's have a wider ridge that would collide with another variant of packaging. The food storage container was one of the containers which was the most interesting. Upon nesting the packaging with another container, it became apparent that a different indentation was utilised for this purpose. Initially, one might have assumed that the packaging was bent to facilitate nesting. This is illustrated by figure 172.

Figure 171: Packaging's used for analysis of nesting

Figure 172: Detail nesting

Figure 173: Detail nesting

This indentation was present on the majority of the examined packages' bottoms. When implementing a nesting ridge, it is essential to ensure that the material behind it cannot flex any further. Keeping this information in mind, the following version was created. This variation utilises the identical embossing as the sleeve attachment. As demonstrated in appendix AG, there has also been a packaging variant with a second bend. However, this version was rejected because the sleeve attachment would be problematic. In figure 173 the final version of the model with embossing is shown.

Appendix AD: Tamperproof

This appendix describes the research that led to the tamper-proof sticker that was chosen. In order to guarantee the quality of the product to the consumer, tamper-proof evidence is essential. Examples of tamper evidence include heat shrink band, tamper evident closures, decorative evident labels, and tamper evident liners [8].

Since it is difficult to recycle, heat shrink band will not be utilised. Because shrink wrap is flexible [14]. Since it must be repeatedly opened and closed, tamper-proof closures are also impossible. The tamper proof evidence will work the first time, but not the second time. The tamper-evident liners will not be considered because the used film is also flexible. Aside from that, the liner is placed within the packaging, and improper removal may leave adhesive residue within the packaging.

Decorative tamper proof labels have been chosen. These labels are placed on the exterior of the packaging to prevent them from coming into contact with any leftover food. Additionally, this type of label is intended to allow the consumer to determine if the packaging has been opened. This is achieved through the use of a label that must be cut [10] or torn [9] to open the packaging.

In the context of this project, it is essential for the customer to be able to determine whether the packaging has been tampered with, but a cut-out label is not required. This should also be avoided, as it requires an additional step from the customer. A label that is easier to open, such as one that tears when twisted, is preferable to one that requires a knife. In addition, tear-off labels are typically constructed from paper and adhesive rather than plastic, making them easier to recycle. These labels can be personalised by the brands whose products will be sold in this packaging.

Appendix AE: Production technique DRD steps

This appendix provides detailed information regarding the DRD steps required for reusable packaging. This appendix was created in collaboration with Henri Kwakkel, the supervisor.

It is necessary to calculate the packaging's surface area in order to determine the number of required steps. Using the measure tool in SolidWorks, this was determined. The total surface area is 65.274 mm2.

The resulting diameter of the blank is 288,3 mm without any slack. The first version calculated to determine the number of required steps included approximately 5% of slack, which corresponds to a 300 mm diameter. To determine the number of required steps, a deep draw ratio must be employed. This is approximately 1.8 for the first step; it could reach 2 but then the material would be at its limit, which could cause it to tear; subsequent steps are lower [A15]. This is due to the fact that the material weakens with each step. The deep draw steps have been determined using this data.

Deep draw step diameter calculation (with 5% slack):

- The first draw (with ratio 1.8) results in a diameter of 167mm.
- The diameter of the second draw (with a ratio of 1.4) is 120mm.
- Third draw (with ratio 1.3) results in a 92mm diameter

As shown in the 3D model of the report, the desired diameter of the can's base is 88mm. Consequently, based on this calculation, the draw would be inadequate, or the 3D model would require modification. After discussion, it was determined that the material becomes thicker at the top of the package after being drawn. This allows the material to be ironed to the proper height. There is no need for a 5% margin of error when ironing the last section. The calculation was altered by increasing the slack to 1 percent. This is a starting diameter of 290 mm.

Deep draw step diameter calculation (with 1% slack):

- The first draw (with ratio 1.8) results in a diameter of 161 mm.
- The second draw (with a ratio of 1.4) results in a diameter of 115 mm.
- Third draw (with ratio 1.3) results in a diameter of 88 mm

During the third draw, the top material is ironed to the same thickness as the rest of the packaging, resulting in a straight end. These variations would produce packaging with the same diameter as the desired design. The tapered design and embossing necessitate a few extra steps.

Material thickness
The thickness of the substrate material must be at least 0.25 millimetres. Which is thicker than standard cans, but necessary given this packaging's larger size. The acceptable thickness maximum is 0.30 millimetres. During the sustainability calculation, it will be determined whether a thicker substrate would be beneficial.

Appendix AF: Injection moulded edge & captechnique DRD steps

This appendix contains additional information about the injection moulds that were designed. Before designing any moulds, it is necessary to determine if the part can be injection moulded. SolidWorks Plastics was used to simulate how a part would be filled and to determine if the required forces to fill the part are sufficient. Following the simulation, additional analyses were performed to determine whether the parts could be injection moulded. After conducting this analysis, and some modifications were made. This appendix contains both the modifications made and the final design of the cap and edge mould.

Cap

The simulation was started by analysing the cap. PET was chosen as the simulation material. To ensure that the injection point residue would be on the inside of the cap, one injection point was placed at the bottom of the cap. Thus, the exterior of the cap would be smooth to touch.

Simulations demonstrated that the required injection moulding pressure is less than 66% of the maximum pressure limit for the part. The end-of-fill temperature is within 10 degrees of the initial temperature, ensuring that the material's quality is maintained. Figure 174 displays that the fill time is 1.4 seconds.

The maximum cooling time for the cap is shown in Figure 175 as 10.7 seconds. The majority of the component, however, is cooled within two seconds, as shown by the blue hue in the figure.

The fill pressure required to injection mould the part is shown in Figure 176 at a maximum of 24.77 MPa. Figure 177 also demonstrates how easy it is to injection mould the entire part by illustrating how simple the fill is. This figure shows that the entire part is easy to fill.

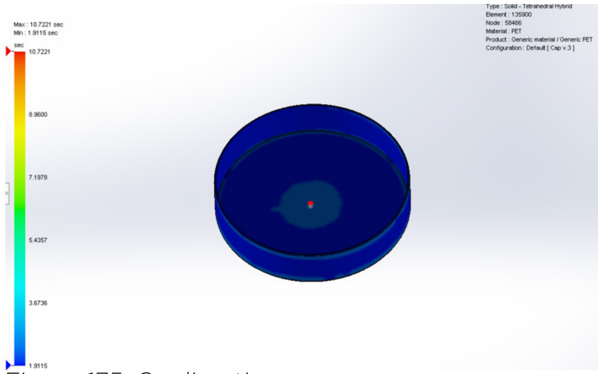


Figure 175: Cooling time cap

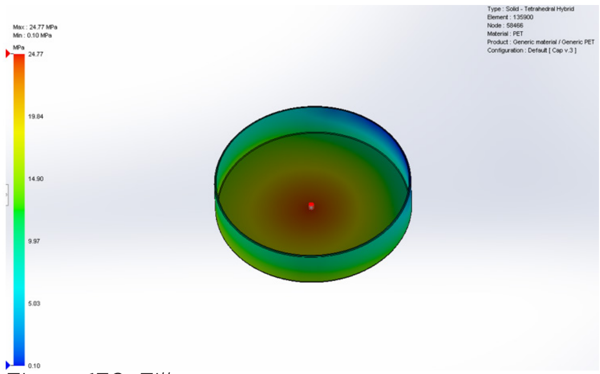


Figure 176: Fill pressure can

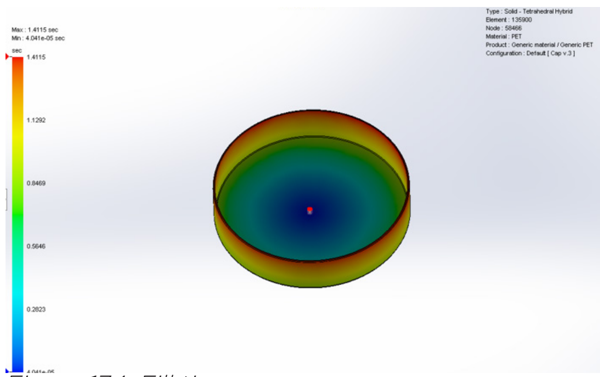


Figure 174: Fill time cap

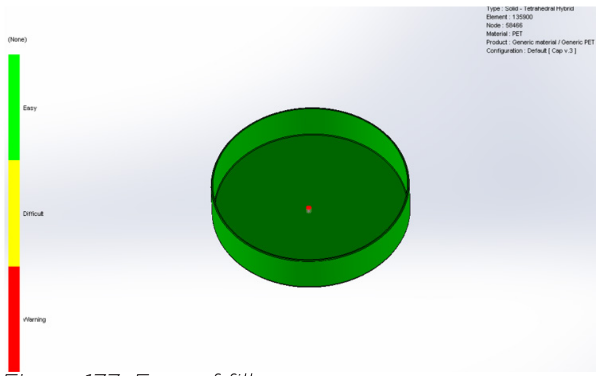


Figure 177: Ease of fill cap

Making sure the draft angles are adequate is the next step before designing a mould. This is essential for injection moulds; otherwise, the part will adhere to the mould and be more challenging to remove. According to research [13], for parts longer than 25 mm, a minimum angle of one degree is required. However, because the created part is not that long, a different draft angle is used. To ensure that the part is released, a minimum angle of 0.5 degrees must be set for it.

The results of adding this draft angle to SolidWorks' draft analysis are shown in Figure 178. The figure shows the draft analysis of the cap's underside. The green portion can be removed when creating a mould from this side, whereas the red sides must be included when creating a mould from the top side. Figure 179 depicts the draft analysis of the top side, which reveals that the sides of the top part can be removed.

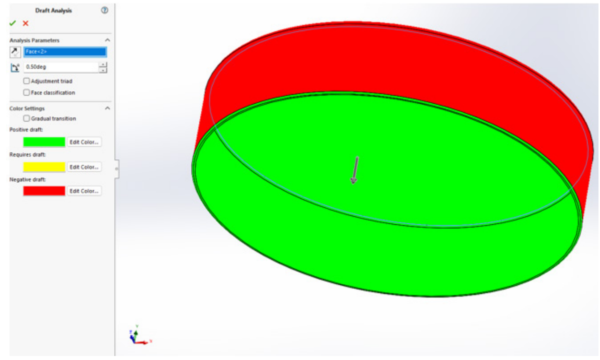


Figure 178: Draft analysis bottom of cap

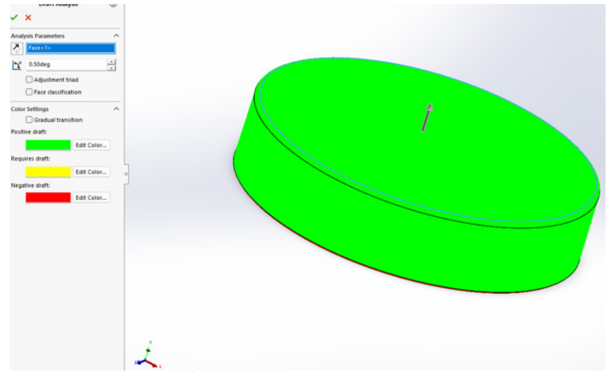


Figure 179: Draft analysis on top cap

The final step was to design the mould, as shown in figure 180. The mould must be refined before it can be used for the final product. Air vents and, if necessary, pins that push the part out of the mould must be added. The mould is composed of two parts, as shown in Figure 181. The injection point was added to the model to show where it should be. Figure 181 shows an exploded view of the two-part injection mould and cap.

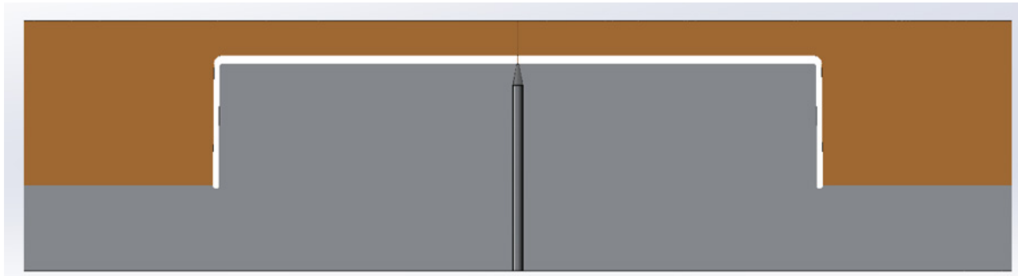


Figure 180: Intersection mould design for cap

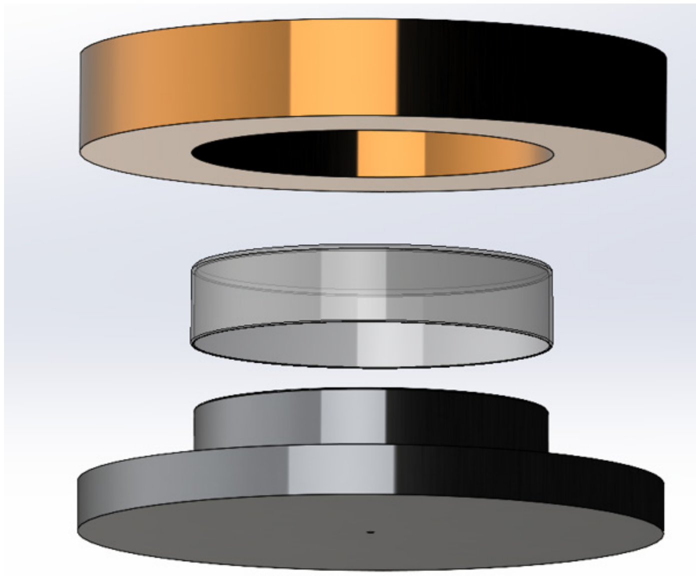


Figure 181: Exploded view mould cap

Injection moulded edge

The injection-moulded edge was the second component to be simulated, but some modifications were required to make it possible. The original edge design (illustrated in Figure 182) was too rounded, making injection moulding impossible without expensive equipment. As depicted in the figures below, the bottom edge was rounded so that it could connect to the main can.

Figure 182: Injection mould to edge before change

The modified design was used to generate simulations of injection mould. Due to insufficient pressure, the first simulation only allowed for partial filling of the part. Consequently, a second simulation with two injection points was performed, and the results were sufficient. The part can now be injection moulded with less than 66% of the maximum allowed pressure, and the temperature difference between the injection point and end melt temperature is less than 10 degrees Celsius. Figure 183 depicts the fill time, which is approximately 0.1 seconds, and Figure 184 depicts the cooling time, which is approximately 1.3 seconds. The part can be filled to a maximum pressure of 44.26 MPa (figure 185). The filling process was also evaluated, and the entire component was able to be filled without difficulty (Figure 186).

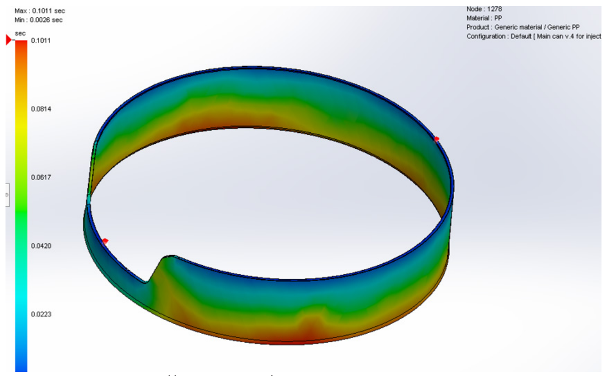


Figure 183: FIll time edge

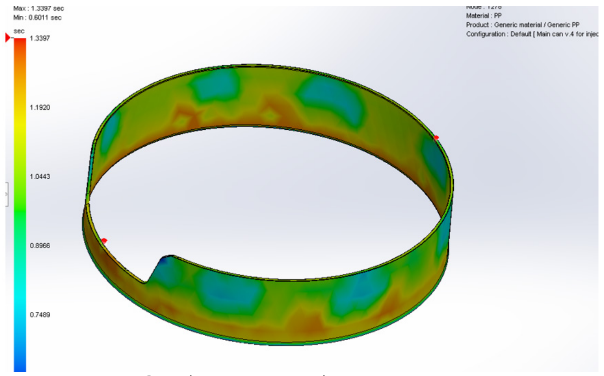


Figure 184: Cooling time edge

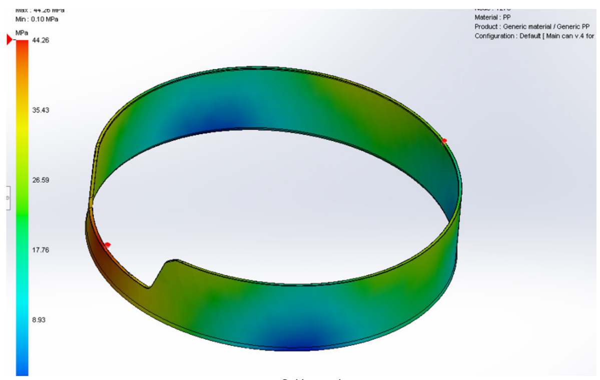


Figure 185: Pressure to fill edge

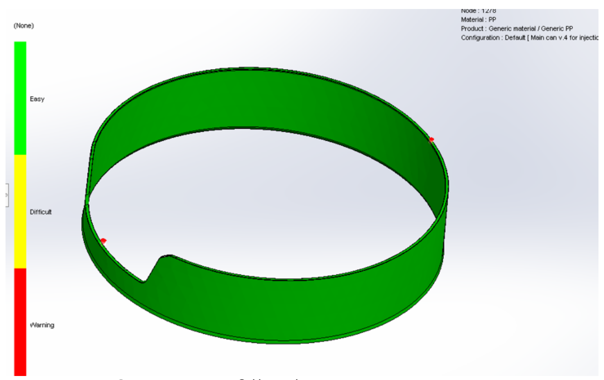


Figure 186: Ease to fill edge

The edge was also examined using draft angles, just like the cap section. However, since the edge is moulded to the part, only one draft analysis is required, as shown in Figure 187. This analysis shows that the entire edge can be released.

The mould design was then created for illustration purposes, figure 188. Before the mould can be used, however, more research is necessary. The mould is composed of two parts: the upper part shapes and seals the edge where the material will be injected, while the lower part secures the can. As is illustrated in figure 189.

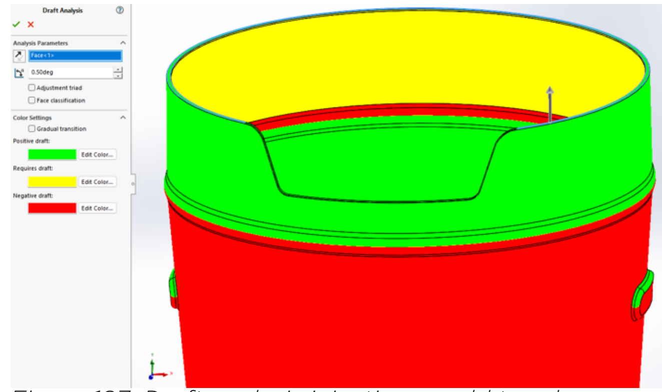


Figure 187: Draft analysis injection mould to edge

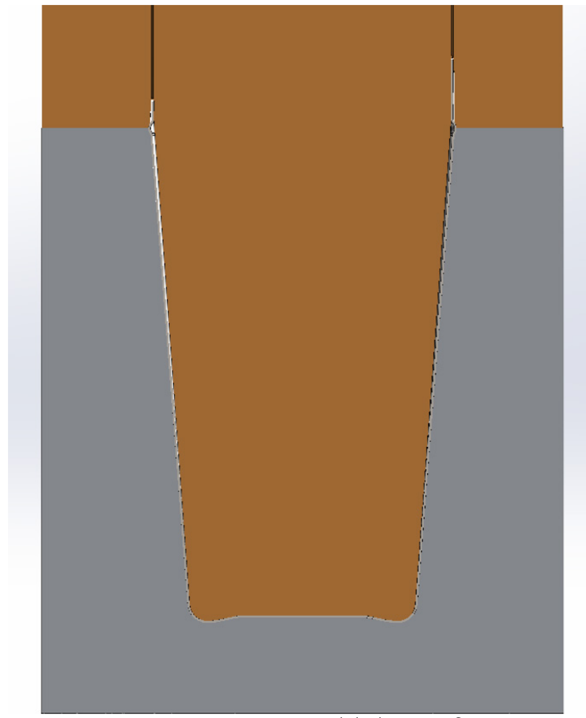


Figure 188: Intersection mould design for injection mould edge

Figure 189: Exploded view injection mould to edge

Appendix AF: Injection moulded edge & captechnique DRD steps

In this section, the development of the 3D model is described in detail. As there were multiple versions created prior to the final version. This appendix also includes size and filling tests using a 3D-printed model.

The first 3D model of the concept has been designed for easy pour testing. It was a straightforward design that could be nested. Figure 190 shows one of the two 3D-printed models. They were printed at a scale of 65%, making them smaller than the standard version. This is because printing two copies took less time. This model's grip is about the size of a peanut butter pot. However, only a small amount of food could fit inside the packaging, and for reusable packaging, it is essential that it can at least meet the standard size, though a bit more would be preferable. The grip of these models was assessed with female hands. It is easy to hold and pour with one hand.

Figure 190: First 3D printed model

Figure 191 shows the second 3D model created (version 1). It was essential that the first version closely resembled the concept sketch. The model was then modified to ensure it's technical feasibility.

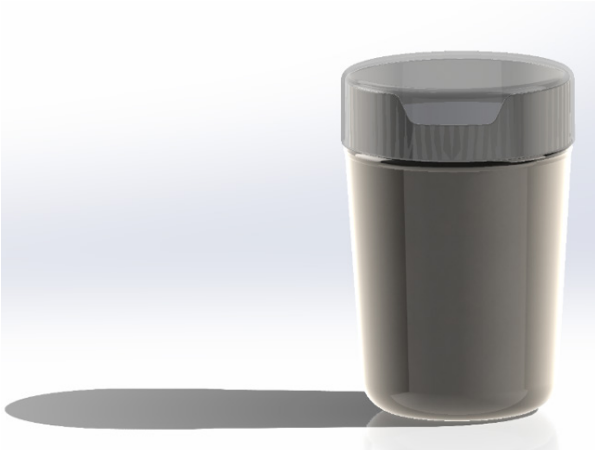


Figure 191: 3D model v.1

After designing this model, it became clear that the bend needed to be significantly lowered in order to ensure nesting. Because it would not be aesthetically pleasing for the bend to be that low, it was decided to try a different approach by incorporating a second bend into the material. By including this, version 2 was created. As depicted in figure 192.

Figure 192: 3D model v.2

However, it was determined that a revised version was necessary. There was some worry about the sleeve's attachment because of the additional bend. Because of this, more bends had to be avoided. Even though it is anticipated that it will be necessary for the production of the packaging, as bends from previous deep drawing steps will still be visible. This is not anticipated to be a significant issue, however, as these bends will be smaller than the one depicted in figure 192. Version 3 of the 3D model does not include a second bend, but rather a slightly lowered top bend. To still be able to ensure nesting. This model was also created with a thinner wall thickness; versions 1 and 2 had a thickness of 1.5 mm, while version 3 had a thickness of 0.75 mm. This allowed for higher nesting. The third iteration of the 3D model is shown in Figure 193. This model also includes the injection-moulded edge and sleeve.

Figure 193: 3D model v.3

The packaging needed to be printed and physically held in order to properly test the design. The packaging was 3D printed. This model was utilised to assess whether the fit was suitable for both small and large hands. The volume and sleeve attachment will also be tested with this model (to ensure that the sleeve fits the packaging perfectly).

The first test was performed with female hands. They were small female hands, and to see the difference, larger male hands were also tested.

The size was comparable to the current packaging, but a significant difference was observed: the current rectangular packaging is easier to hold because one side is thinner. This is not possible with rounded packaging; in order for the packaging to hold as much food as the current packaging, it must have a smaller diameter and a greater height.

Additionally, only the female hand was used to test the grip while holding food. Since the breakfast cereal is not heavy relative to its volume, it does not significantly affect grip. It was possible to pour the food while holding the packaging. On a smooth surface, for instance, the packaging does feel as though it could slip out of the hand. Figure 194 depicts the grip of female hand and figure 195 depict the grip with male hand.

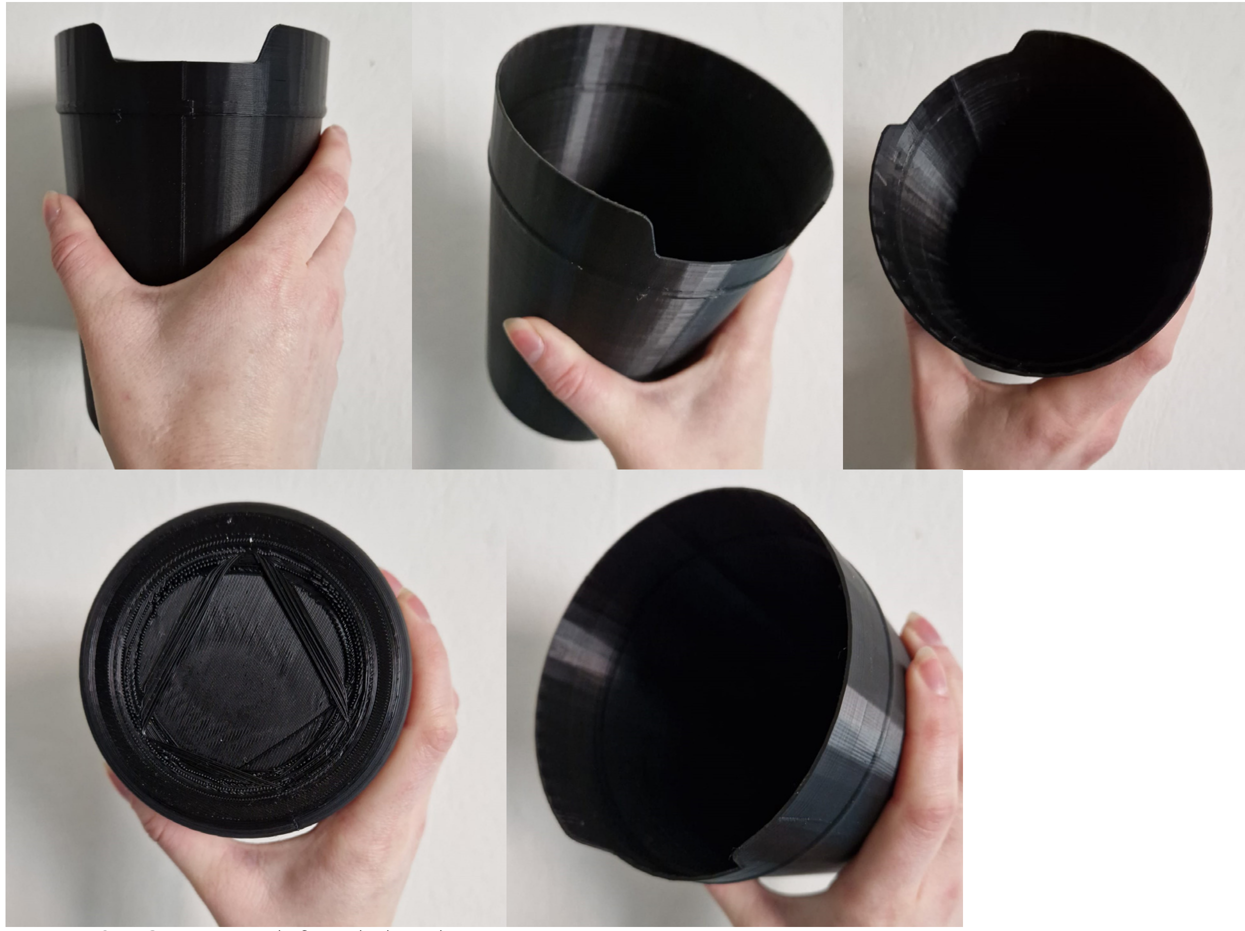


Figure 194: Grip v.3 with female hands

Figure 195: Grip v.3 with male hands

To determine whether the volume measurements in appendix Z are accurate, the 3D model created for grip testing will also be used to determine how much food can fit inside. The volume that should fit inside the packaging is 1200 cm3 based on the volume measured in SolidWorks with a 10% headspace. Using the measurement taken, it was possible to estimate how much food should theoretically fit inside this packaging. The packaging was estimated to hold 526 grammes of Cruesli Luchtig. However, when the packaging was filled with Cruesli Luchtig, the maximum weight of the contents appeared to be significantly lower. See figure 196. Approximately 420 grammes could fit inside the packaging as a whole. This difference could be the result of a measurement error or another factor. For example, the use of a rounded shape rather than a rectangular shape when measuring.

The measurement was repeated using Kellogg's Smacks. The maximum weight that the packaging could fit was 208 grammes. The maximum permissible weight with sufficient headroom was approximately 195 grammes. This demonstrates that measurements have a margin of error. This must be considered when designing version 4 of the 3D model.

This 3D model was also used to calculate the volume collapse. After being filled, the packaging has been shaken and vibrated by lifting it slightly and dropping it on the countertop. This was done several times until there was no longer any noticeable difference. Figure 197 depicts before and after shaking was performed. The before also demonstrates that a hill is visible prior to the shaking. This is because the food forms a pyramidal shape when poured from the same location. This hill disappeared after the shaking, leaving the food's top more evenly dispersed.

Figure 196: Volume weight measurement (Cruesli Luchtig)

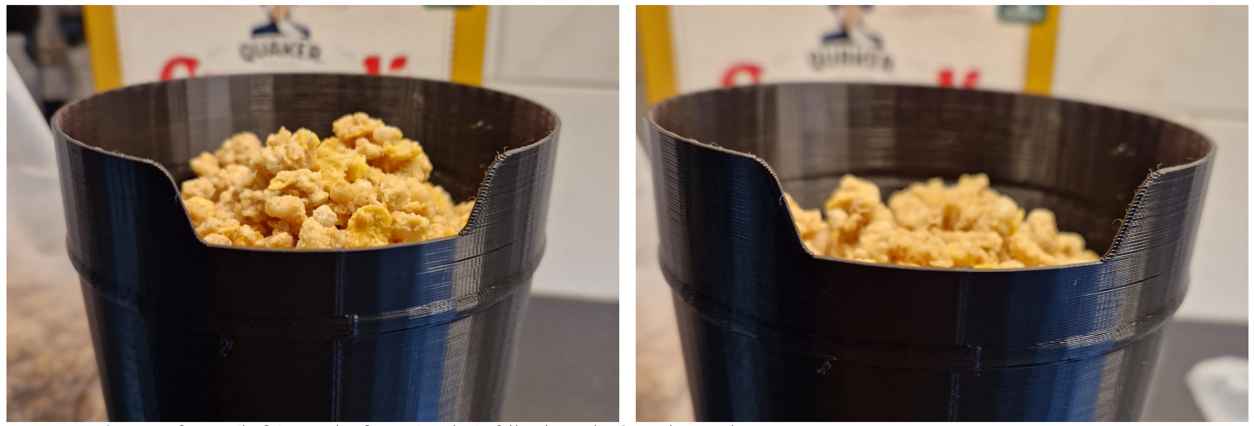


Figure 197: Before (left) and after (right) filled with Crusli Luchtig

The discoveries made during testing of this version of the 3D model will be taken into account when creating version four. Version four was also 3D printed in order to test the grip with the new dimensions. Which is also the first thing that has been examined. With the same female hand and male hand as the previous version.

In version 4, the 3D model's grip was improved. Even when held for longer periods of time, the hands are much more relaxed and show no signs of strain when holding the packaging. Figure 198 depicts the female hand holding the model, while figure 199 depicts the male hand.

Figure 198: Grip v.4 with female hands

Figure 199: Grip v.4 with male hands

Version v.4 is the final version because it appears to be a good fit for both smaller female hands and larger male hands. This model will be utilised to develop the necessary additional research, including the LCA and the business model.

This model has a slightly larger volume than model v.3. This is the reason why more food content can fit into this container, approximately 450 g. The model's content is shown in Figure 200.

There could be more content, but when the container is overfilled, the first moment of pouring is made more difficult because more food falls from the top. Cruesli Luchtig has a maximum weight of 500 g, after which the packaging is filled to just above the bend.

Figure 200: Weight measurement v.4

Appendix AH: Supermarket exploration for food choice Protact®

Due to the fact that Protact® was not created with reusability in mind, it is necessary to investigate food options that could be combined with this material. There is a risk of oxidation because Protact® is composed of multiple layers with metal (steel) in between. Especially when the packaging is frequently reused and a sharp tool is required to remove the product from the inside. This scratching may cause holes in the layers that protect the steel, allowing it to oxidise. The rate at which the material resists scratching will be studied, but in order to get started and have backup products that can still be used without scratching, a supermarket exploration was conducted. During the trip to the grocery store, the following considerations were made: since the packaging will be made of metal, it will be impossible to see through it and squeeze it (without damaging it beyond repair). Products requiring such properties are therefore excluded. The products under investigation fall into three categories: non-scratching, in-between, and scratching. Even if the material is not scratch-resistant, it is still possible to choose non-scratching products, as scratch resistance is not required for these kinds of items. Table 8 displays the three food groups.

Table 8: Three food groups (scratching)

Non-scratching	In-between	scratching
Rice	Vegetables in can	Peanut butter (and other condi-ments)
Spagetti	Custard	Butter
Macaroni	Yogurt	Asperges in pot
Fusili	Fruit in can	Tuna in can
Soups	Cruesli	Pots of pasta sauses
Milk	Seeds	Coffee (powder)
Cakemixes (powder form)	Nuts	
Pancake mixes	Flower	
Sugar	Coffee (beans)	
Chocolate sprinkles		
Rusk (biscuit)		
Tea (in bags)		
Chips		
Liquid sauces (maggi, ketjap)		
Cookies		
Smoothies		
Coffee (pads)		

Additionally, scratching causes the material to oxidise. This is also accelerated by the use of a liquid, as water is an electrolyte solution that promotes rusting. As a result, another division has been created. The food groups were divided into three categories: moist, semi-moist, and dry. Based on these characteristics, Table 9 displays the three food groups.

Table 9: Three food groups (moisture)

Moist	Semi-moist	Dry
Vegatables in can	Custard	Chips
Yogurt	Peanut butter (and other condi-ments)	Cookies
Fruit in can	Butter	Coffee (pads)
Soups	Pasta sauses	Coffee (powder/beans)
Milk		Cruesli
Asperges in pot		Rice
Tuna in can		Spagetti
Liquid sauces (maggi, ketjap)		Macaroni
Smoothies		Fusili
		Seeds
		Nuts
		Flower
		Cakemixes (powder form)
		Pancake mixes
		Sugar
		Chocolate sprinkles
		Rusk (biscuit)
		Tea (in bags

When selecting the optimal food product for use with Protact®, it is essential to consider both non-scratching and dry options. This leads to the following food item:

- Dry pasta's
  - Rice
  - Spagetti
  - Macaroni
- Fusilli
- Cereal
- Sugar
- Flower
- Powder food mixes (like cake mixes)
- Sprinkles (chocolate)
- Rusk (biscuit)
- Tea (in bags)
- Cookies (long expiration dates)
- Coffee (pads/beans)

In addition to these differences in food products, it is useful to examine the current packaging materials for these foods in order to identify the areas where the most significant changes could be made. What customers do with the packaging after it has been opened will also be taken into account. Table 10 contains the packaging components.

Table 10: Three food groups (moisture)

Food	Current packaging	Home storage
Dry pasta's	Plastics and cardboard	Plastic and storage containers
(Breakfast) cereal	Cardboard box in combination with plastic bag	Storage containers
Sugar	Paper bag	Storage containers
Powder food mixes	Cardboard box with paper bag inside	Disposed after use
Sprinkles	Cardboard box	In packaging or container
Rusk (biscuit)	Plastic with protection layer	In packaging or container
Coffee (pads/beans)	Plastic (multilayer)	Packaging or container
Cookies	Plastic	Disposed after use

This table demonstrates that the most intriguing options are those that involve packaging that is discarded and from which the food contents are placed in a storage container (as this could be combined with the packaging when it is made of metal) and from which the packaging is currently made of an unrecyclable material. This leaves the following options: dry pasta, cereal, rusk, and coffee (pads/beans).

All of these options could be utilised for reusable Protact® packaging. However, for this assignment, a specific food product must be chosen. The design of the packaging will not be limited to the food item that has been chosen at this time. It is possible to fill the packaging with other types of dry foods that do not scratch or have other methods for removing the contents. (Breakfast) cereal is the selected food category. This is because cereals are packaged in cardboard and plastic (even though plastic might be exchanged for something a bit more environmentally friendlier in the future, they still need some barrier to protect it from air). Cereals are delicate and easily broken, so they are transported with a substantial amount of air. They need this additional air to survive the journey. When it is filled, it does not immediately straighten out, so there is also extra space for that. It is anticipated that a metal cereal package can be shrunk in size without causing damage to the cereal during transport. This would indirectly result in more eco-friendly packaging because more cereal could be transported at once and it would take up less space in the grocery store than the current cereal packaging.

Appendix AI: Barriers breakfast cereal

Several factors must be considered when designing packaging for breakfast cereal. These include exposure to air, water, and light [A16,A17,A18]. In addition to cereal, breakfast cereal frequently contains fruit and chocolate.

Cereals absorb water and become soggy when exposed to it [A16,A18]. This process is undesirable, it causes the product to degrade unintentionally (when not consumed right away). Even cereal mould growth may result from this [A17].

Another factor that causes cereal to deteriorate and lose flavour is exposure to oxygen. The cereal will also become less crisp [A17]. Cereal will oxidise more quickly the longer it is exposed to oxygen.

As previously stated, breakfast cereals frequently include chocolate and fruit. These have their own limitations as well. When it comes to fruits and chocolate, one barrier is particularly sensitive. This is exposure to heat/sunlight. Figure 201 depicts how sunburn would occur on exposed fruits; however, since cereals typically contain dried fruits, this should not be a major concern [A19]. Chocolate exposed to sunlight will develop fat bloom (figure 202), which, while not detrimental to the product's quality, is unappealing [A20].


Figure 201: Sunburnt fruit [1]


Figure 202: Fat bloom on chocolate [2]

Appendix AJ: Breakfast cereal brands

There are numerous brands of breakfast cereal available worldwide. This section will list the top European brands [A21]. Cereals from the United States can be used, but their exorbitant prices in Europe prevent them from being taken into account when comparing cereal brands.

1. Kellogs
2. Weetabix Limited
3. General Mills
4. Quaker Oats
5. Nestle Cereals

Appendix AK: History breakfast cereal

Cereal and a variety of other ingredients are combined to create breakfast cereal. Cereals are typically made from oats, corn, wheat or rice [A22,A23]. The breakfast cereals can be sweetened or left unsweetened by adding artificial sweeteners, fruits, or chocolate. Cereals are frequently consumed for breakfast with milk, yoghurt, or on their own.

Over the past few decades, processed grains have been utilised as a nutritious source of human nutrition [A24]. However, humans consumed predominantly meat-based breakfasts. Which resulted in digestive issues. Due to this and the nineteenth-century vegetarian movement, food reform has begun [A24].

The first breakfast cereal was created in 1854 by Ferdinant Schumacher. He produced oats by hand and sold them in his own shop, the American Cereal Company [A24,A25]. In the United States, the first company to manufacture oats was founded in 1977; it later became the Quaker Oats Company [A25,A26,A27]. Around the same time, James Caleb Jackson creates Granola. George H. Hoyt then created wheatena and began selling it in boxes rather than by the pound. These variants, however, were not particularly well-liked because they needed to be soaked overnight before consumption [A25,A26].

John Harvey Kellogg, a physician at the time, desired to create a version of food that was lighter and less flavourful for his patients. However, while experimenting, he and his brother accidentally invented cornflakes [A25]. By adding sugar to the cereals, William Keith's younger brother began discrediting the health claim and marketing the cereal as a tasty convenience [A28]. After this, cereal boxes became a breakfast mainstay, and a variety of alternatives emerged. The colourful box was an essential marketing asset used to cultivate customer loyalty [18]. The 6 billion euro breakfast cereal industry in Europe remained extremely popular in 2016.

Appendix AL: Portfolio Quaker Oats Company

The complete list of Quaker products can be found in this appendix. These are separated into six categories: cruesli, cruesli colours, oatmeal, granola, muesli, and in between. The products on this list are all available in Europe; the United States has more options, but they are not the focus of this project.

Product portfolio:

- Cruesli
  - Chocolate
  - 4 nuts
  - Cookies & cream
  - Raisins
  - Multifruit
  - Apple & raisins
  - Red fruits
  - Light
  - Frambalicious
  - Zero sugar added strawberry & peach
  - Zero sugar added cocoa & banana
  - Zero sugar added apple, pecan & cinnamon
- Cruesli colours
  - Orange (orange, apple and raspberry)
  - Pink (strawberry, chocolate and pistachio)
  - Yellow (mango, blueberry and pumpkin seeds)
- Oatmeal
  - Oatmeal
  - Oatmeal express
- Granola
  - Chunky baked nuts & seeds
  - Chunky bakes original
  - Balance original
  - Full of fiber
  - Energy activation mix
- Muesli
  - Multifruit
  - Nuts
- In between (No breakfast cereal)
  - Oat bars chocolate
  - Oat bars golden syrup

Most of their cruesli packages are 450 grammes, but they also offer 375-gram options (Light and frambalicious). They also offer larger family-sized packaging ranging from 800 to 850 grammes.

Appendix AM: Design rationale

Several factors must be considered when designing the label that will serve as an example for this project. When designing a label for a particular company, in this case Quaker Oats Company, it is essential to consider their brand language and the elements they use when creating their packaging. This must be considered, as the reusable packaging should closely resemble Quaker Oats Company's current product line. This will ensure that consumers recognise the product and are familiar with the brand.

The brand language of a portfolio can be determined by examining its various products and identifying similarities between them. A summary of some Quaker products is provided in figure 203. Using this image, these similarities have been determined.

Figure 203: Overview portfolio Quaker Oats Company

As depicted in figure 203, the different types of packaging share a number of characteristics. These include the logo, product name, product type, and a product image. Figure 204 lists and illustrates these features on an example packaging.

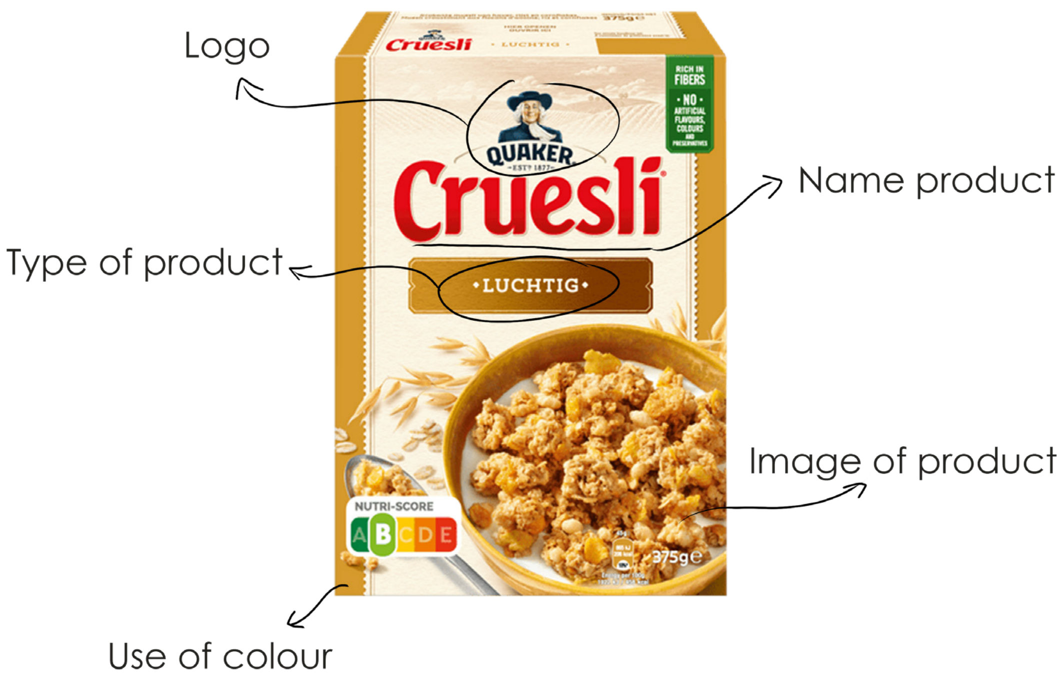


Figure 204: Similar aspects packaging Quaker

The product's name, such as Cruesli or Oats, is the most prominent feature on each packaging. The size and colour of these words make them noticeable. They are distinguished by vibrant hues or stark contrasts with the background. Because of this, they are the first thing noticed when examining the packaging. They shouldn't be significantly altered because consumers can recognise them.

The product type is the second most significant factor. Typically displayed in a coloured box or a colour distinct from the background. The packaging for Cruesli Balans demonstrates this (fig. 203). Once a product has been identified, it is essential for consumers to know its category and type.

The third component is colour usage. Each product category has its own packaging colour. Which allows consumers to identify their preferred product type based solely on the packaging colour. The colour must therefore be prominently displayed on the packaging.

The brand's logo appears on each package as the fourth component. There are two variations of this logo: one with full colour and detail and the other with fewer elements. It appears that the logo on more recent packaging has been simplified and no longer appears in full colour.

The image of the food is the final aspect that is similar to the packaging but uses a different image. This allows consumers to see which product is inside the packaging without opening it. They are able to recognise the image and, as a result, determine which of the two appears more attractive to them. This aspect is assumed to be the least significant of the named aspects. As the product's other characteristics already guarantee consumer recognition. It should also be noted that when the product can be seen through the packaging, it may not be necessary to include an image of the food at all.

In addition to this information, additional details are visible on the packaging. These are the nutri-score, the label indicating that the food is high in fibre, the nutritional information (a condensed version on the front), and the amount of food. On the back of the packaging, there is additional information about the food's composition.

Graphical exploration

The next step in the design rationale is the graphical exploration. In this section, the previously mentioned elements will be eliminated and their impact on the packaging's appearance will be demonstrated. This enables the determination of which information should be retained on the reusable packaging and which can be removed to simplify the packaging. Figure 205 depicts the first exploratory graphic.

Figure 205: Graphical exploration 1

Figure 205 depicts the front of a Quaker Cruesli package. Beginning with all current information and concluding with nothing but coloured bars on the front. The ability to identify the food is unaffected by removing the brand from these variants. When the brand is removed, however, the consumer is uncertain as to whether the product is authentic Quaker cruesli or another brand. The brand must therefore survive. Figure 206 contains the second graphical exploration. This image exhibits additional variation. This was done to determine if removing colour affects the product's recognizability and if the word Cruesli is necessary to identify the brand. This highlights the significance of both colour and text. Those who are unfamiliar with the brand must also know the type, as they would not be able to identify the type based on its colour; the same is true for those who are colourblind.

Figure 206: Graphical exploration 2

Appendix AN: Weight of the packaging

Using a calculation tool from Tata Steel, the weight of the blank and, by extension, the weight of the packaging can be determined. Figure 207 shows a picture of this tool with all the required fields filled out.

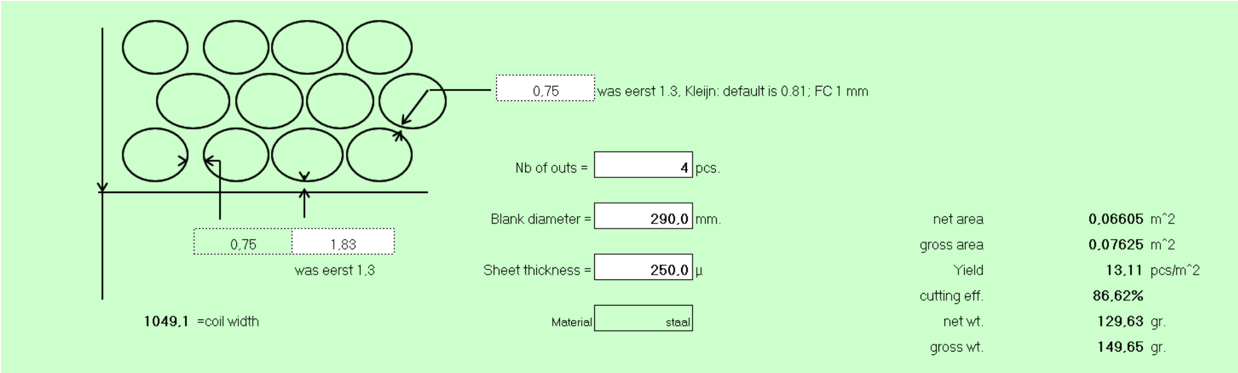


Figure 207: Calculation tool weight sheet

This calculation reveals that the steel weighs 150 g gross and 130 g net. To calculate the weight of Protact® coating, multiply the surface area by the thickness of the PP coating, which must be multiplied twice because the coating is on both sides.

Volume of PP coating = 2 * 65274 * 0.04 = 5221.92 mm3 = 5.2219 x 10-6 m3

To determine the weight of the PP coating, the GrantaEdupack database was consulted. This demonstrates that the density of PP is between 895 and 909 kg/m3. The PP coating should weigh roughly 5,2219 x 10-6 *900 = 4,7 x 10-3 kg = 4,7 gramme using the density and volume.

Finally, the weight of the injection-moulded edge must be added to the total weight of the main can. This will also be made from PP. The injection mould has a volume of 2574.75 mm3, which is equal to 2.7475 x 10-6 m3. Using the same density as Granta Edupack, the weight is determined to be 2.5 grammes.

The main packaging is made of steel, coating, and injection mould. The total weight is 137,2 grammes (130+4,7+2.5).

Sleeve
The surface area of the folding box board multiplied by its thickness can also be used to calculate the volume of the sleeve. The collected surface area from Solidworks is 55728.26 mm2, or 0.056 m2. To be considered board, the FBB grammage must be at least 160 g/m2 [12]. Most folding box board weighs between 200 and 600 g/m2. For this application, 200 g/m2 was selected. The calculated weight of the packaging is 0.056 x 200 = 11.2 grammes.

Cap
Finally, the cap's weight will be estimated. The same calculation was used to determine the cap's weight. The volume of the cap is initially measured using Solidworks. The cap has a volume of 22103.75 mm3, or 2,204 x 10-5 m3. According to GrantaEdupack, PET has a density of 1.29e3-1.39e3 kg/m3. The cap weighs 2,204 x 10-5 * 1.35 x 103 = 0,0297 kg = 29,7 grammes.

Appendix AO: Cost price calculation

To provide an estimate of the necessary investment and packaging costs, a cost calculation has been performed. The injection-moulded components were created using an Excel spreadsheet, this excel sheet has been provided by Saxion Enschede. This Excel spreadsheet will be filled with GrantaEdupack data. The main can, sleeve, injection mould to edge, and cap are the components that will be elaborated upon.

Before determining the cost per unit, the quantity of products to be manufactured has a significant impact on the final result. There are 746,4 million people living in Europe, where the product can be sold. If 1% of the European population consumed breakfast every day and purchased new packaging every week, 500 million cans would be sold annually. Given that this packaging is intended for multiple reuses, it is estimated that 500,000 new cans will be sold annually if the packaging is reused 100 times.

Cap

The cap is the first factor of the cost price. Injection moulding and PET are used to make this. The Excel spreadsheet has been populated with data obtained from the previous appendix. The information from PET in Granta Edupack has also been utilised. The simulation results of the Solidworks injection mould were used to determine the filling time.

A. Anemaat [A29] developed the estimated costs for the necessary mould. The required mould can produce a single piece at a time, has a surface area of 254,5 dm2, and is not complicated. This yields an estimated mould cost of 10.380 euros.

A single tool can mould between 10,000 and 1,000,000 units (information from GrantaEdupack). The production costs are significantly impacted by this number. The injection-moulded cap will be produced using a simple mould with few moving parts; as a result, it is expected that this mould will last longer. The mould is estimated to be capable of producing at least 150.000 pieces. When more items can be manufactured with a single tool, the cost of the mould decreases.

According to GrantaEdupack, injection moulding machine investment costs range from 2.700 to 682.000 euro. The amount selected for the cap is 40.000 euro. This is also due to the simplicity of the part. This amount has a five-year write-off period; if the customer desires a shorter write-off period, the product will be more expensive in the first period.

The Excel spreadsheet used for this section is shown in Figure 208. This result indicates a unit price of 0.19 euro. The majority of which can be attributed to tooling expenses. Increasing the number of units that can be produced per tool has a significant effect on total costs. The number of units selected at this time is estimated to be the bare minimum that can be produced with a tool, so this number can only decrease.

Onderdeelnaam	**Cap**	**Samenvatting Geamortiseerd**			
Tekeningnummer	**Part_0004**	Totaal	0,19	euro	
		Shaping	0,18	0,031	Waarvan materiaal
				0,083	Waarvan matrijs
				0,055	Waarvan machine + rest
				0,013	Nabewerking
		Joining	0,00		
		Surface	0,00		
		Assemblage	0,01		
		Investering in onderdeelgebonden gereedschap	10380	**euro**	

Productie aantal (totaal te produceren)	500000	onderdelen		
Shaping process	Spuitgieten			
Cyclustijd in seconden	1,4	seconden		
voudigheid van matrijs	1			
Productie per uur (shaping)	2.571	onderdelen		
Werkuren per dag	14	uren		
Productie per dag	28800			
Productiedagen	17			
Productiedagen per jaar	275			
Materiaalkosten:				
Materiaalsoort	PET		**f-factor**	
Volume	0,022104	dm3	product gewicht	0,20
Soortelijke massa	1,34	kg/dm3	totaal gewicht van	0,21
Procuctgewicht	0,03	kg	f-factor	0,05
afvalfactor f	0,01			
Gebruikt gewicht	0,03	kg		
Prijs/kg	1,04	euro / kg		
Gebruiksmaterialen / onderdeel	0,00			
Materiaalkosten / onderdeel			**0,03**	**euro / onderdeel**
Gereedschapskosten				
Totale gereedschapskosten voor het onderdeel	10380	euro		
Aantal producten per gereedschap	150000	producten		
Benodigde gereedschappen	4			
Gereedschapskosten per onderdeel			**0,08**	**euro / onderdeel**
Machinekosten				
Aanschaf van machine (rente op investering	40000	euro		
Afschrijf termijn	5	jaar		
Load factor	0,8	uren gebruik / uren		
Machinekosten / onderdeel			**0,00**	**euro / onderdeel**
Overhead incl. arbeid, administratie, rente				
Tarief per uur	18	euro/uur		
Overhead per onderdeel			**0,04**	**euro / onderdeel**
Mens per machine verhouding	5	mens / machine		
Energie kosten				
Tarief per uur	40	euro / uur		
Energie per onderdeel			**0,02**	**euro / onderdeel**
Royalty payments				
Royalty	0	royalty/onderdeel		
Totaal aan royalty	0	royalty	**0,00**	**euro / onderdeel**
Onderzoek en ontwikkeling				
Tijd in ontwikkeling	20	uur		
Ontwikkeltarief	75	euro/uur		
Ontwikkelkosten	1500	Ontwikkeling		
Ontwikkelkosten per onderdeel			**0,003**	**euro / onderdeel**
			0,05	
Nabewerking	1	seconden / onderdeel	0,013333333	**euro / onderdeel**
Machinetarief	30	machinetarief		
Tarief per uur	18	euro/uur		
	1	mens / machine		

Figure 208: Cost calculation cap

This Excel sheet can also be used to display the variation in unit price based on the quantity of units produced. Figure 209 illustrates the distinctions for the cap. The unit price decreases as more units are produced.

Shaping kosten bij verschillende aantallen		Shaping materiaal	matrijs	machine+rest	nabewerking
Aantallen	Totaal				
1	41.520,11	0,03	41.520,00	0,05	0,01
10	4.152,11	0,03	4.152,00	0,05	0,01
100	415,31	0,03	415,20	0,05	0,01
1000	41,63	0,03	41,52	0,05	0,01
10000	4,26	0,03	4,15	0,05	0,01
100000	0,52	0,03	0,42	0,05	0,01
1000000	0,15	0,03	0,04	0,05	0,01

Figure 209: Costs with different unit amounts cap

Injection mould to edge

The injection mould to the edge will be the next component to be calculated. This component necessitates a simple, non-complex injection mould, which reduces the injection mould's cost. This mould would have a 274,6 dm2 surface area. This would also result in an estimated mould cost of 10.380 euros [A29].

It is estimated that the number of units that can be produced for this section is larger than the previous part. As the material is injection moulded to the can. Aside from this, the amount of PP used to mould the can is low. Because of this, it is estimated that a single mould can produce 250.000 units.

Since the difference in surface area between this mould and the previously mentioned mould is negligible, it is anticipated that the machine costs will be comparable. Similarly, this is estimated to cost 40.000 euro. However, because the machine has a 5-year write-off period, the costs of the machine will not increase production prices unless the costs of the machine exceed one million euro.

This component has no assembly costs because it is injection-moulded to the edge and requires no additional assembly. Figure 210 depicts the injection mould to edge cost calculation. Eight cents per unit is the total cost of this part. Figure 211 depicts the differences between unit amounts for this item.

Onderdeelnaam	**Injection moulded edge**	**Samenvatting Geamortiseerd**			
Tekeningnummer	**Part_0003**	Totaal	0,08	euro	
		Shaping	0,08	0,00	Waarvan materiaal
				0,04	Waarvan matrijs
				0,01	Waarvan machine + rest
				0,03	Nabewerking
		Joining	0,00		
		Surface	0,00		
		Assemblage	0,00		
		Investering in onderdeelgebonden gereedschap	10380	**euro**	

Productie aantal (totaal te produceren)	500000	onderdelen			
Shaping process	Spuitgieten				
Cyclustijd in seconden	0,15	seconden			
voudigheid van matrijs	1				
Productie per uur (shaping)	24.000	onderdelen			
Werkuren per dag	14	uren			
Productie per dag	268800				
Productiedagen	2				
Productiedagen per jaar	275				
Materiaalkosten:					
Materiaalsoort	PP		**f-factor**		
Volume	0,002575	dm3	product gewicht	0,20	
Soortelijke massa	0,902	kg/dm3	totaal gewicht van	0,21	
Procuctgewicht	0,00	kg	f-factor	0,05	
afvalfactor f	0,01				
Gebruikt gewicht	0,00	kg			
Prijs/kg	1,04	euro / kg			
Gebruiksmaterialen / onderdeel	0,00				
Materiaalkosten / onderdeel				**0,002**	**euro / onderdeel**
Gereedschapskosten					
Totale gereedschapskosten voor het onderdeel	10380	euro			
Aantal producten per gereedschap	250000	producten			
Benodigde gereedschappen	2				
Gereedschapskosten per onderdeel				**0,04**	**euro / onderdeel**
Machinekosten					
Aanschaf van machine (rente op investering	40000	euro			
Afschrijf termijn	5	jaar			
Load factor	0,8	uren gebruik / uren			
Machinekosten / onderdeel			**0,00**		**euro / onderdeel**
Overhead incl. arbeid, administratie, rente					
Tarief per uur	18	euro/uur			
Overhead per onderdeel			**0,00**		**euro / onderdeel**
Mens per machine verhouding	5	mens / machine			
Energie kosten					
Tarief per uur	40	euro / uur			
Energie per onderdeel			**0,00**		**euro / onderdeel**
Royalty payments					
Royalty	0	royalty/onderdeel			
Totaal aan royalty	0	royalty	**0,00**		**euro / onderdeel**
Onderzoek en ontwikkeling					
Tijd in ontwikkeling	20	uur			
Ontwikkeltarief	75	euro/uur			
Ontwikkelkosten	1500	Ontwikkeling			
Ontwikkelkosten per onderdeel			**0,003**		**euro / onderdeel**
				0,01	
Nabewerking	1,5	seconden / onderdeel		0,03125	**euro / onderdeel**
Machinetarief	30	machinetarief			
Tarief per uur	45	euro/uur			
	1	mens / machine			

Figure 210: Cost calculation injection mould to edge

Shaping kosten bij verschillende aantallen		Shaping			
Aantallen	Totaal	materiaal	matrijs	machine+rest	nabewerking
1	20.760,04	0,00	20.760,00	0,01	0,03
10	2.076,04	0,00	2.076,00	0,01	0,03
100	207,64	0,00	207,60	0,01	0,03
1000	20,80	0,00	20,76	0,01	0,03
10000	2,12	0,00	2,08	0,01	0,03
100000	0,25	0,00	0,21	0,01	0,03
1000000	0,06	0,00	0,02	0,01	0,03

Figure 211: Costs with different unit amounts injection mould to edge

Main can

For the main can, a new Excel sheet had to be created. Particularly for the draw and redraw step. A few perimeters were added to the modified Excel spreadsheet. For instance, the tooling costs associated with deep drawing per step and additional ironing costs. These tooling costs were calculated using GrantaEdupack, but Henri Kwakkel was also consulted.

The material costs have been estimated using GrantaEdupack steel and PP prices. The Protact® joining procedure has also been added as a cost per hour. As this is accomplished rapidly and in large quantities.

To determine the cost of purchasing the machine, GrantaEdupack and Henri's knowledge were utilised. This demonstrates a price range of 80.200 to 802.000 euros. Henri asserts, however, that machine costs for comparable can lines are typically much higher. For this reason, it was estimated that the machine would cost approximately 5 million euros. Due to the fact that the primary can-making machine requires at least three drawing steps and three additional shaping steps.

The cost of tooling is proportional to the cost per mould and the number of units that can be produced using these tools. According to GrantaEdupack, a deep draw necessitates a tooling change between 10.000 and 100.000 units. However, it is estimated for the tooling to be able to produce a lot more pieces before tooling change is required, this is estimated to be at 5 million units. Mould costs are estimated at 75.000 euros per piece for the drawing stages. As these are quite large components. The moulds for the additional steps were estimated to cost 5.000 euros each.

The main can's cost calculation is shown in Figure 212. The primary can is anticipated to cost 0.48 euro per unit. Figure 213 also displays the costs in relation to the number of units.

Onderdeelnaam	**Main can**	**Samenvatting Geamortiseerd**		
Tekeningnummer	**Part_0001**	Totaal	0,48	euro
		Shaping	0,35	0,21 Waarvan materiaal
				0,05 Waarvan matrijs
				0,10 Waarvan machine + rest
				0,01 Nabewerking
		Joining	0,00	
		Surface	0,00	
		Assemblage	0,00	
		Investering in onderdeelgebonden gereedschap	243000	**euro**

Total production units	500000	units		
Shaping process	Draw redraw (and ironing)			
Total draws required	3			
Total additional shaping steps	3			
Units created in one draw	1			
Cyclustime total draw process	1	seconds		
Prodction per hour	3.600	units		
Working hours per day	14	hours		
Production per day	95.760			
Production days	4			
Total production day per year	275			
Material costs:				
Type of material (total)	Steel and PP			
Types of material	Steel			
Blank diameter	290	mm		
Sheet thickness	250	u		
Netto wt.	129,6269121	gr		
Waste rate	0,134			
Used weight	149,68	gr		
Price per ton	1200	euro		
Price per gram	0,0012	euro		
Price per unit	0,180		75% scrap	
Types of material	PP			
Volume	0,00522	dm3		
Mass	0,902	kg/dm3		
Weigth	0,00470844	kg		
Waste rate	0,01			
Used weigth	0,00476			
Price/kg	1,04			
Material costs/ part	0			
Joining process protact:				
Cost per hour	50	euro/hour	0,03	euro/unit
Overhead per part				
Human per machine	2	human/machine		
			0,21	euro/unit
Tooling costs				
Deep drawing costs:				
Tooling costs per step	75000	euro		
Total units per tool	5000000	unit		
Needed tools for production units	0,1			
Additional costs ironing step	3000	euro		
Additional shaping costs:				
Tooling costs per step	5000	euro		
Total units per tool	5000000	unit		
Needed tools for production	0,1			
Total tooling costs (all steps)	243000	euro	**0,05**	euro/unit
Machine costs				
Purchase of machine	5000000	euro		
Write-off period	5	years		
Load factor machine costs/unit	1,9	hours	0,02	euro/unit
Overhead incl. labour				
Rate per hour	50	euro/hour		
Overhead per unit				
Human per machine	3	human/machine	0,04	euro/unit
Energy costs				
Rate per hour	30	euro/hour		
Energie per part			0,01	euro/unit
Research & development				
Time to develop	100	hour		
Development rate	150	euro/hour		
Development costs	15000			
Development costs per unit			0,03	euro/unit
Total machine and rest			**0,10**	
Post-processing				
Time	0,5	seconds		
Machine rate	30	euro/hour		
Rate per hour human	30	euro/hour		
Human per machine	0,2	human/machine	**0,01**	euro/unit

Figure 212: Cost calculation injection mould to edge

Shaping kosten bij verschillende		Shaping materiaal	matrijs	machine+rest	nabewerking
Aantallen	Totaal				
1	24.300,31	0,21	24.300,00	0,10	0,01
10	2.430,31	0,21	2.430,00	0,10	0,01
100	243,31	0,21	243,00	0,10	0,01
1000	24,61	0,21	24,30	0,10	0,01
10000	2,74	0,21	2,43	0,10	0,01
100000	0,56	0,21	0,24	0,10	0,01
1000000	0,34	0,21	0,02	0,10	0,01

Figure 213: Costs with different unit amounts injection mould to edge

Sleeve

The final component that must be calculated is the sleeve. The sleeve is made of folding boxboard and offset printed. As this allows the sleeves to be printed in high quality and large quantities [A30]. This component does not require a mould, so there are no initial investment costs. To determine the write-off period of an offset printer, research was conducted. The offset printer and cutter are expected to cost $20.000 each. Changing this number has little effect on the product's final price, so the estimate can fluctuate.

For the weight of the sleeve, a 25% waste rate was used. The waste rate shows how much product is discarded. Due to the curved nature of the sleeve, there are numerous components that must be discarded, resulting in a high rate of waste.

The selected tooling costs are associated with the ink used during printing. To determine the number of pages that can be printed using industrial ink cartridges, a calculation was required. Given that it is not specified how many pages can be printed with, say, 300ml of ink (black). According to information from brother black ink, 60ml is equivalent to approximately 3.000 pages (using only black ink) [A31]. This corresponds to approximately 500 pages per 10 ml. For 300 ml, this is equivalent to approximately 15.000 pages of A4 paper or 7500 sleeves (as this fits inside an A3 paper, with some adjusting more pages could be printed). Using this information, the price for 7.500 sleeves has been determined to be 340 euros. This also includes the ink for coloured prints.

The outcome of the calculation is shown in Figure 214. This indicates that the estimated cost price for the sleeve is 0.14 euros. Figure 215 displays the price in relation to the quantity of units sold.

Onderdeelnaam	Sleeve	Samenvatting Geamortiseerd			
Tekeningnummer	Part_0002	Totaal	0,14	euro	
		Shaping	0,09	0,01	Waarvan materiaal
				0,05	Waarvan matrijs
				0,02	Waarvan machine + rest
				0,01	Nabewerking
		Joining	0,00		
		Surface	0,00		
		Assemblage	0,04		
		Investering in onderdeelgebonden gereedschap	340	**euro**	

Productie aantal (totaal te produceren)	500000	onderdelen			
Shaping process	Laser cutting and printing				
Cyclustijd in seconden	3	seconden			
voudigheid van matrijs	1				
Productie per uur (shaping)	1.200	onderdelen			
Werkuren per dag	14	uren			
Productie per dag	16800				
Productiedagen	30				
Productiedagen per jaar	275				
Materiaalkosten:					
Materiaalsoort	Folding box board		**f-factor**		
			product gewicht	0,20	
Product weight	0,0112	kg	totaal gewicht van	0,21	
Procuctgewicht	0,0112	kg	f-factor	0,05	
afvalfactor f	0,25				
Gebruikt gewicht	0,0149	kg			
Prijs/kg	0,959	euro / kg			
Gebruiksmaterialen / onderdeel	0,00				
Materiaalkosten / onderdeel				**0,014**	**euro / onderdeel**
Gereedschapskosten					
Totale gereedschapskosten voor het onderdeel	340	euro			
Aantal producten per gereedschap	7500	producten			
Benodigde gereedschappen	67				
Gereedschapskosten per onderdeel				**0,05**	**euro / onderdeel**
Machinekosten					
Aanschaf van machine (rente op investering	20000	euro			
Afschrijf termijn	5	jaar			
Load factor	1	uren gebruik / uren			
Machinekosten / onderdeel			**0,00**		**euro / onderdeel**
Overhead incl. arbeid, administratie, rente					
Tarief per uur	45	euro/uur			
Overhead per onderdeel			**0,00**		**euro / onderdeel**
Mens per machine verhouding	0,1	mens / machine			
Energie kosten					
Tarief per uur	20	euro / uur			
Energie per onderdeel			**0,02**		**euro / onderdeel**
Royalty payments					
Royalty	0	royalty/onderdeel			
Totaal aan royalty	0	royalty	**0,00**		**euro / onderdeel**
Onderzoek en ontwikkeling					
Tijd in ontwikkeling	15	uur			
Ontwikkeltarief	100	euro/uur			
Ontwikkelkosten	1500	Ontwikkeling			
Ontwikkelkosten per onderdeel			**0,003**		**euro / onderdeel**
				0,02	
Nabewerking	0,5	seconden / onderdeel		0,010	**euro / onderdeel**
Machinetarief	30	machinetarief			
Tarief per uur	45	euro/uur			
	1	mens / machine			

Figure 214: Cost calculation injection mould to edge

Shaping kosten bij verschillende aantallen

Aantallen	Totaal	Shaping materiaal	matrijs	machine+rest	nabewerking
1	22.780,09	0,01	22.780,00	0,02	0,01
10	2.278,09	0,01	2.278,00	0,02	0,01
100	227,89	0,01	227,80	0,02	0,01
1000	22,87	0,01	22,78	0,02	0,01
10000	2,37	0,01	2,28	0,02	0,01
100000	0,32	0,01	0,23	0,02	0,01
1000000	0,11	0,01	0,02	0,02	0,01

Figure 215: Costs with different unit amounts injection mould to edge

Appendix AP: Sustainability calculation

This appendix contains sections of an LCA comparison of single-use versus reusable packaging. These parts include the inventory analysis, models, and results.

Inventory

Inventory will be utilised to determine all steps performed during the packaging's life cycle. They will be illustrated through the use of a process tree and assembly trees. Then, these can be utilised to create the models of the life cycles in Gabi.

Process tree

Two process trees, one for single-use packaging and the other for reusable packaging, have been developed to illustrate the flow of materials and their respective quantities. In addition to the order and timing of each process and flow, the process trees contain essential components related to their structure.

The disposal phase has been divided into different parts based on the type of waste. Before sorting, it is assumed that 10% of single-use packaging and 5% of reusable packaging are discarded unsorted and sent to the municipal solid waste stream. The remaining packaging will be separated by material. This is evident in the process tree as well. The recycling rates are determined by the following statistics:

Cardboard
Recycling: 68% [A32]
Incineration: 20,2%
Burn/landfill: 11,8% [A33]

Plastic [29]
Recycling: 8%
Incineration: 23%
Burn/landfill: 69%

Steel [A34]
Recycling: 85%
Landfill/burn: 15%

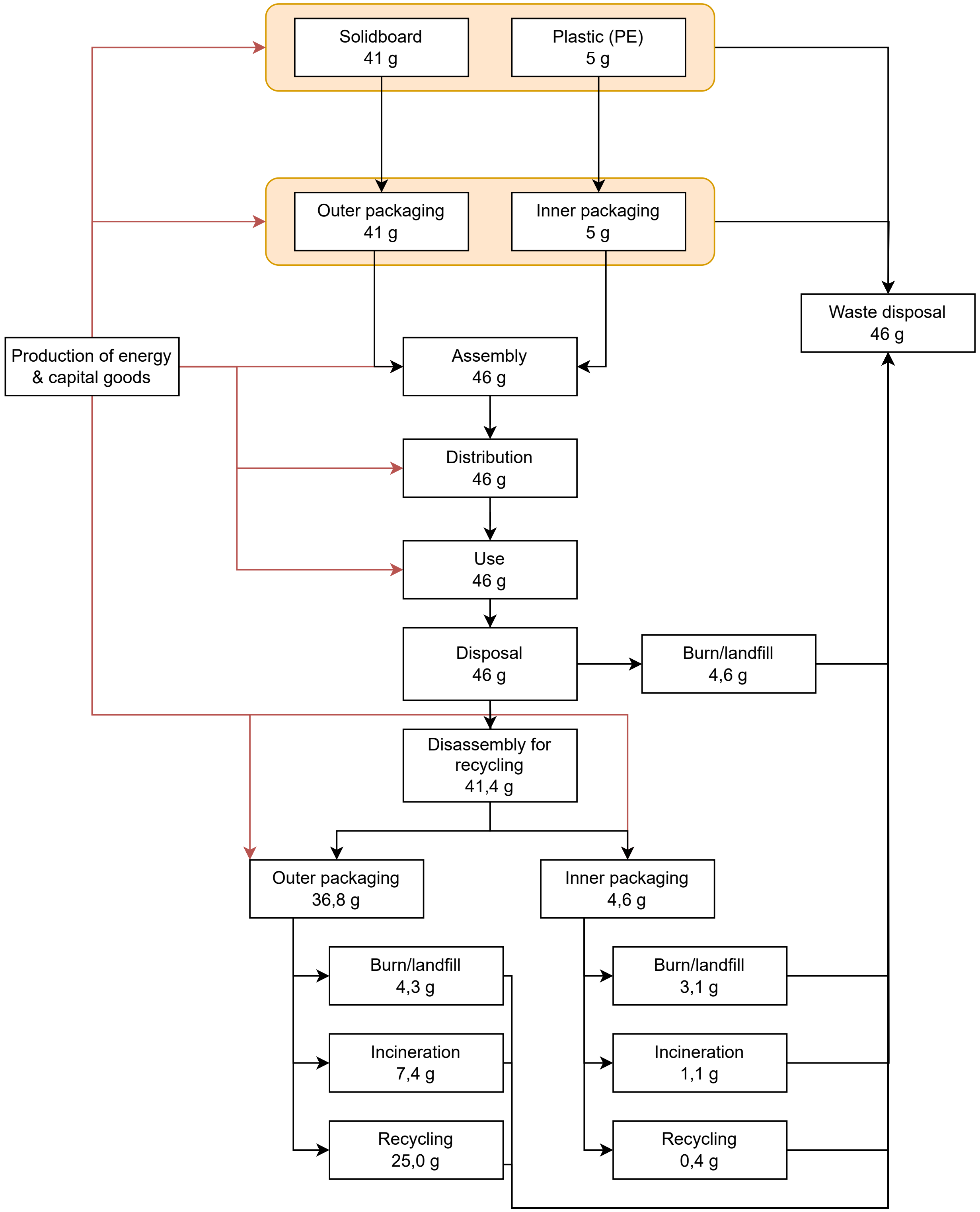


Figure 216: Process tree single-use packaging

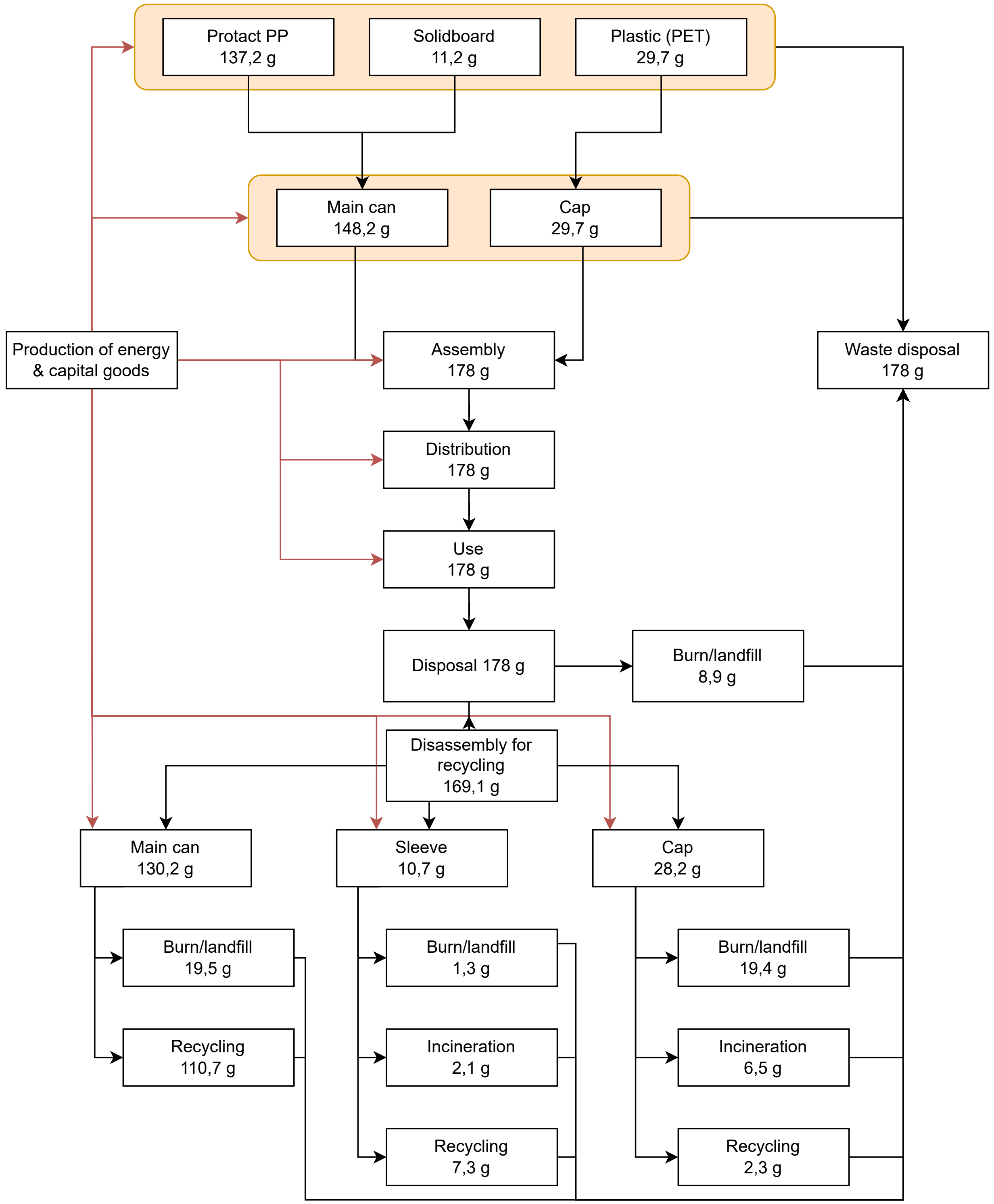


Figure 217: Process tree reusable packaging

Assembly tree

The assembly tree illustrates the products' constituent parts and the assembly process. Figure 218 illustrates the assembly tree for single-use packaging, while Figure 219 illustrates the assembly tree for reusable packaging.

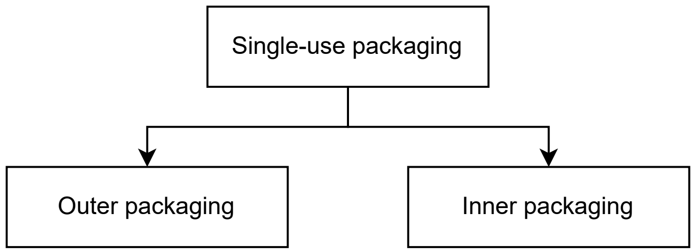


Figure 218: Assembly tree single-use packaging

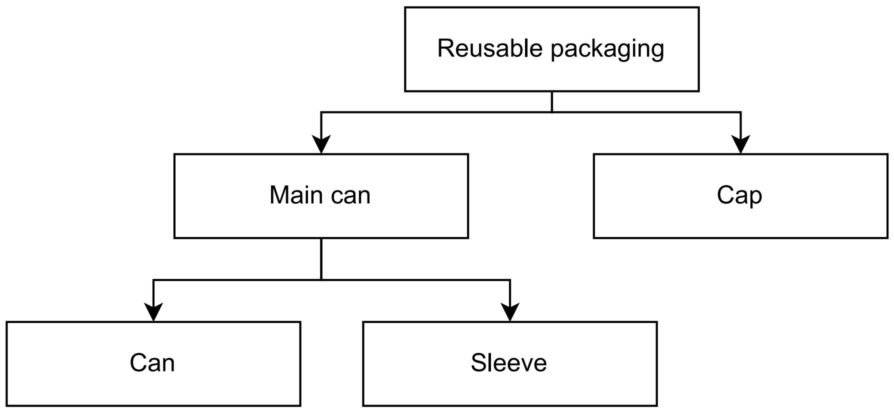


Figure 219: Assembly tree reusable packaging

Models

After creating the process and assembly trees, the Gabi model could be modelled. The following model was used for the packaging's generic model.

The generic base model:
Production - Use - Disposal

The next step was to model the detailed plans for production, use and disposal per packaging type. For the production plan, first a main production plan containing all produced components is created. The plans that follow this main production plan are the production plans for the necessary components.

As stated in the objective definition, the functional unit requires varying numbers of life cycles. In order to be able to compare products, the functional unit must be translated into GaBi models. This is accomplished by the scaling factors of both the single-use packaging and the reusable packaging, each of which will have its own scaling factors based on the functional unit. The single use LC will be modelled per life cycle with a factor of 42 for scaling. While reusable packaging is also modelled per life cycle, it is scaled by a factor of 2,2 because it will be reused 10 times. As this was Loop's minimum requirement. Additionally, more scenarios were created in which the packaging is reused 3, 4, 5,6 and 7 times. In order to determine the break-even point. Figure 220 illustrates the life cycle of the reusable packaging. Since the sleeve is not reusable, multiple sleeves are required per can's life cycle. The amount of washing is also determined by the required number of reuses.

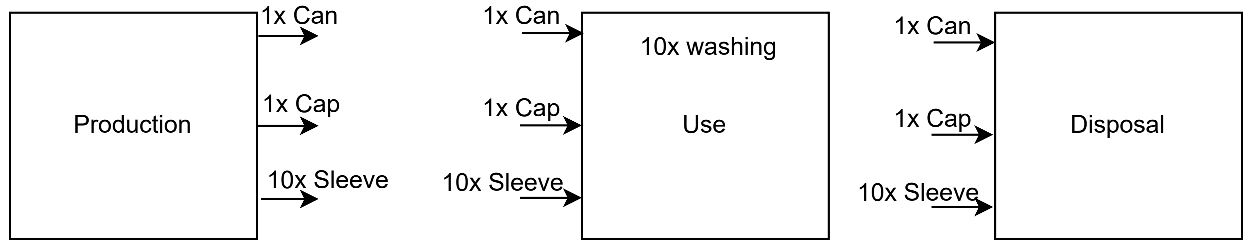


Figure 220: Modelling reusable packaging per life cycle

During the production of each part, some material will be wasted; this is known as cutting losses. For the steel components, the calculated cutting losses will be utilised. While 10% cutting losses will be added to the remaining parts.

Single-use packaging models

Figure 221 illustrate the generic base model of the single use packaging, with the specified flows and in/outputs.

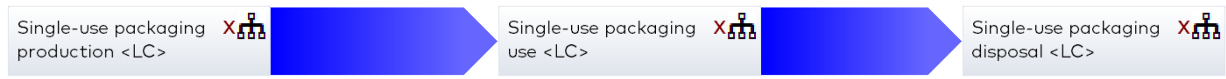


Figure 221: Single-use packaging LC

Production single-use packaging

Figure 222 shows the assembly tree of the single use packaging. This exist out of two part, these are the inner packaging and the outer packaging.

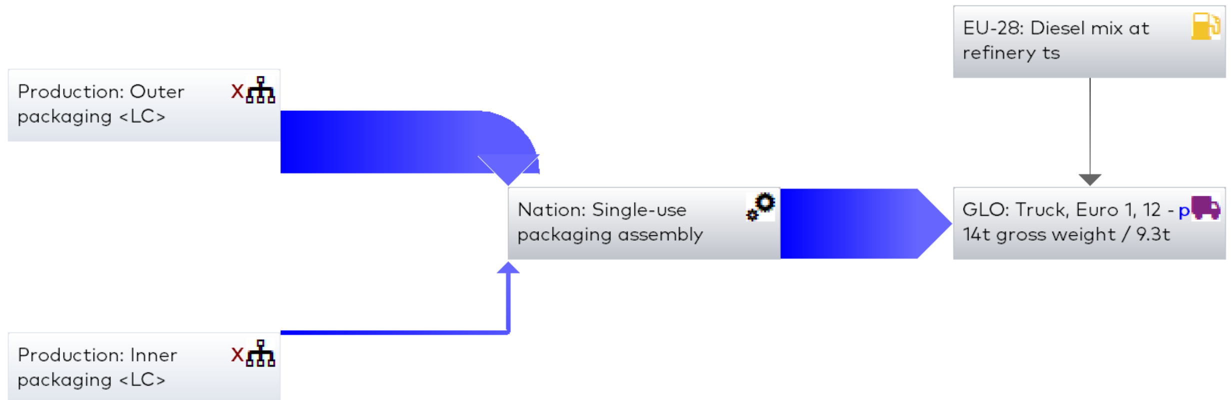


Figure 222: Main production plan single-use packaging

Outer packaging production

Figure 223 shows the outer packaging production plan. This production plan shows the process of folding box board. Since the database was educational, there was no access to the actual folding box board process. This necessitated the creation of the process, which was accomplished with the assistance of a colleague who had access to the process. In the reusable sleeve production plan, the identical process is used.

The electricity flow in the plan has a value of 0 kg, as electricity has no mass, but is an output. This also applies to other electricity-using plans. This plan's electricity consumption is based on an automated box-folding machine [A35]. Which was estimated to consume 0.004 kWh per unit.

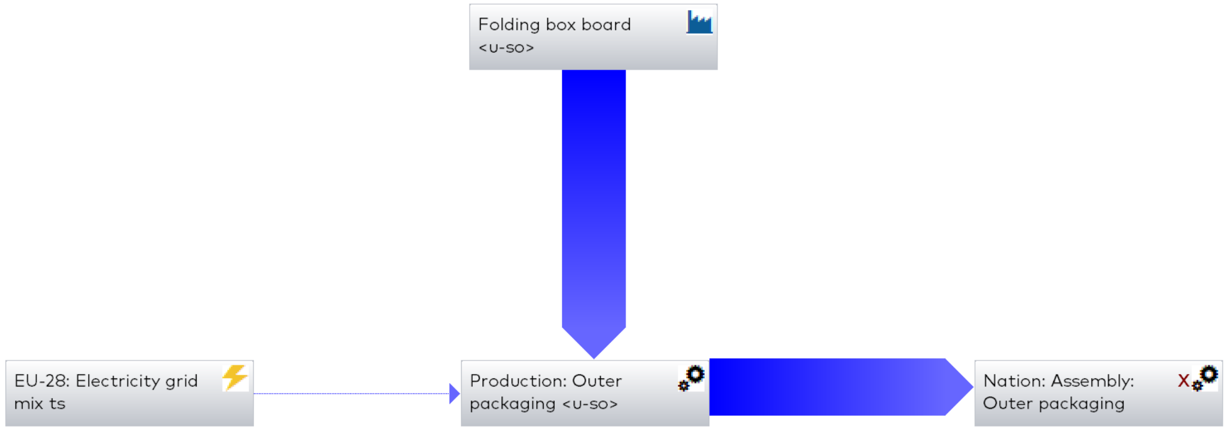


Figure 223: Production plan outer packaging

Inner packaging production

Figure 224 the inner packaging production can be found.

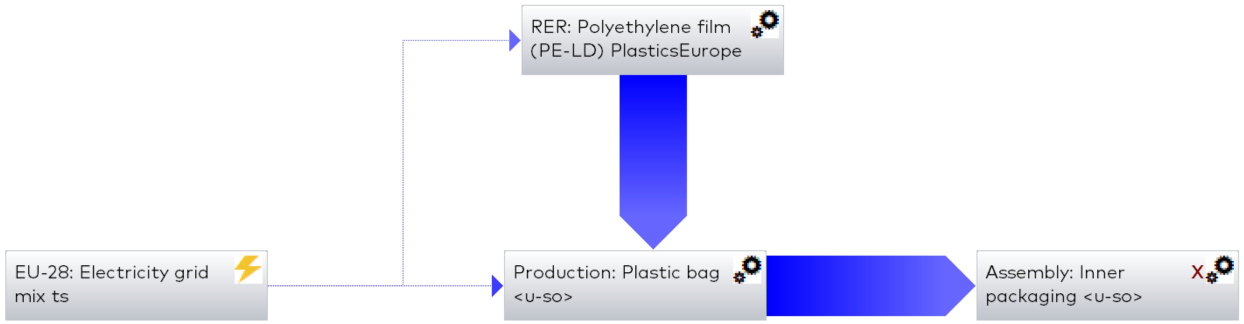


Figure 224: Production plan inner packaging

Use single-use packaging

Figure 225 shows the use phase of the single-use packaging. This solely exist out of using the packaging, after which it is discarded.

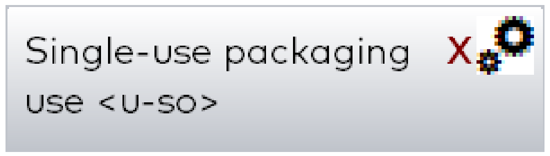


Figure 225: Use single-use packaging

Disposal single-use packaging

Figure 226 the disposal of the single-use packaging can be found. As stated before first a percentage of the entire packaging will be disposed into incineration and after wards it will be separated per material type.

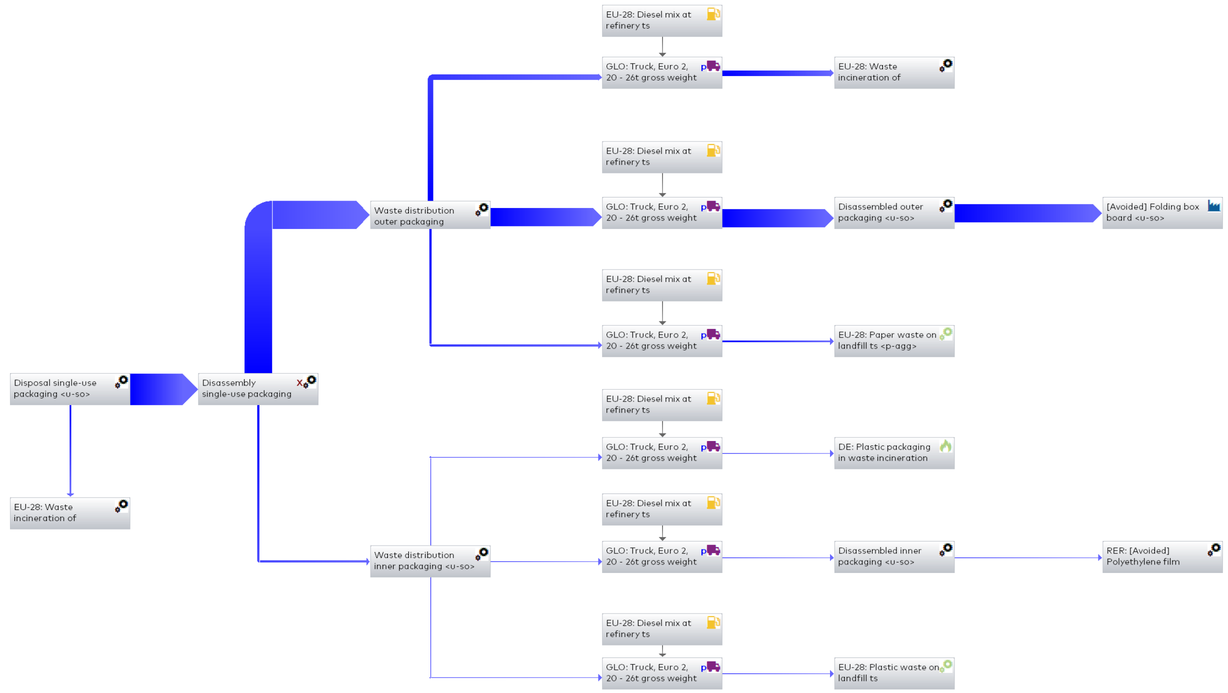


Figure 226: Disposal single-use packaging

In this plan the recycling cycles of the materials are added by using avoided products. This way the materials that are recycled end up lowering the environmental inputs of the products.

Reusable packaging models

Figure 227 the base model of the reusable packaging can be seen.

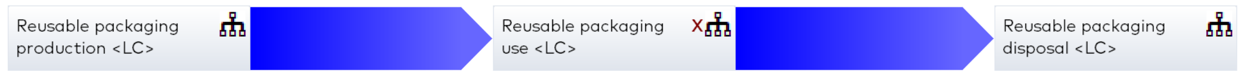


Figure 227: Reusable packaging LC

Production reusable packaging

Figure 228 the production of the reusable packaging can be found. This show the main production model in which the parts are assembled. The reusable packaging exist out of three parts which are the can, the cap and the sleeve.

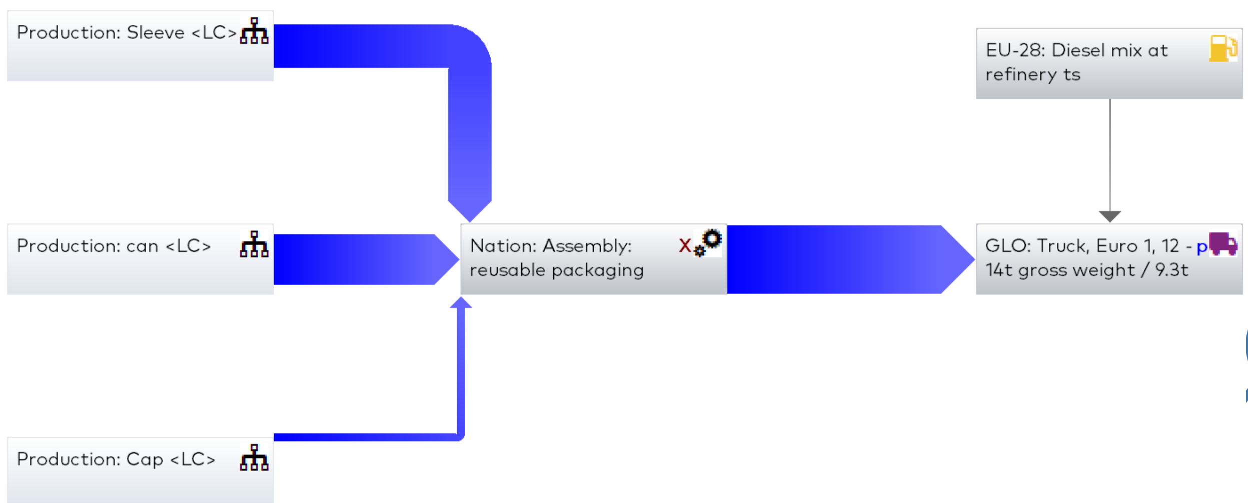


Figure 228: Main production plan reusable packaging

Sleeve production

Figure 229 depicts the production plan for the sleeve. This also utilised the folding box board process described in the production plan for single-use outer packaging. In this plan, the energy required to add the sleeve to the main can is included. This is based on the same source as the single-use packaging's outer packaging. It is assumed that the energy required to attach the sleeve to the main can is less than that required to fold the single-use packaging, but it was determined that the input for both cardboard pieces should remain the same. As it is also unknown how much energy is required to remove the sleeve from its packaging prior to washing.

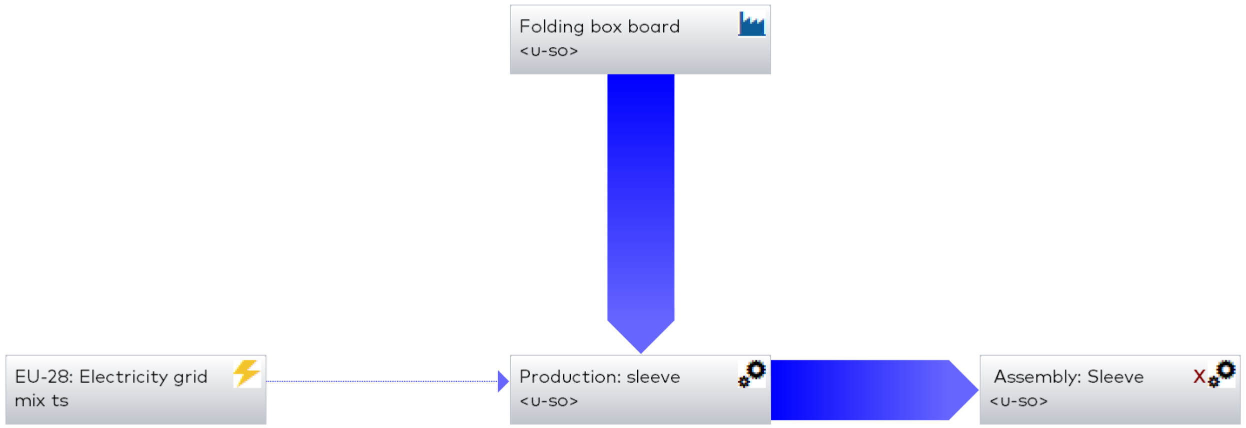


Figure 229: Production plan sleeve

Can production

Figure 230 depicts the production plan for the can. This plan involves the creation of a simplified version of the Protact® production. These figures are based on information provided by Tata Steel, which can be requested from the company. This plan also includes injection moulding, as the main can's edge will be injection moulded to protect it from corrosion.

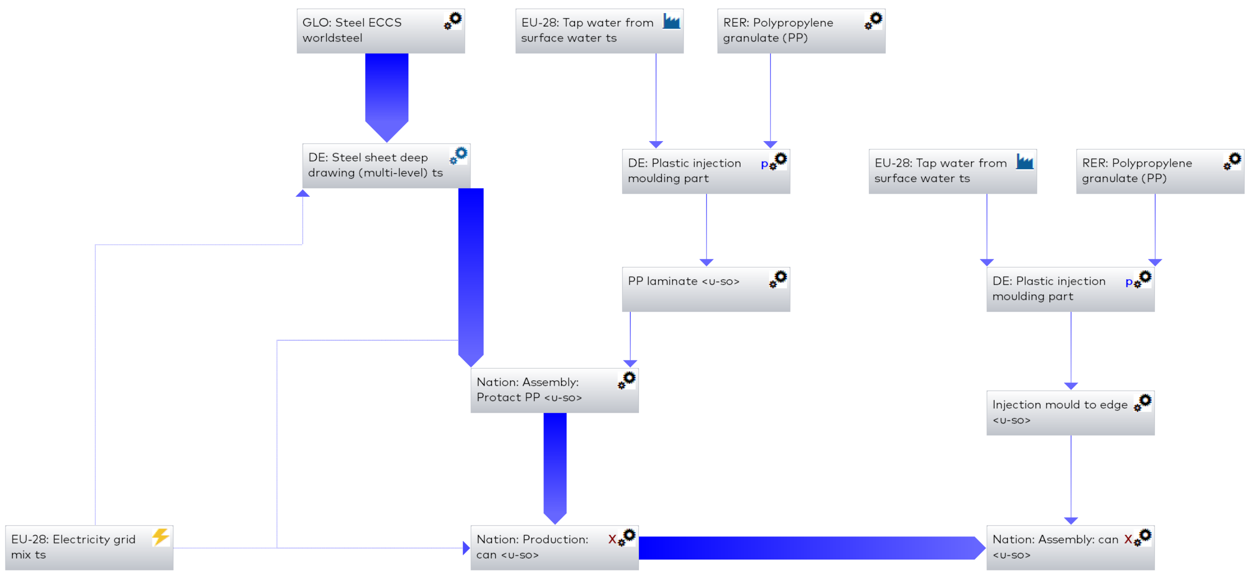


Figure 230: Production plan can

Cap production

Figure 231 shows the production plan of the cap.

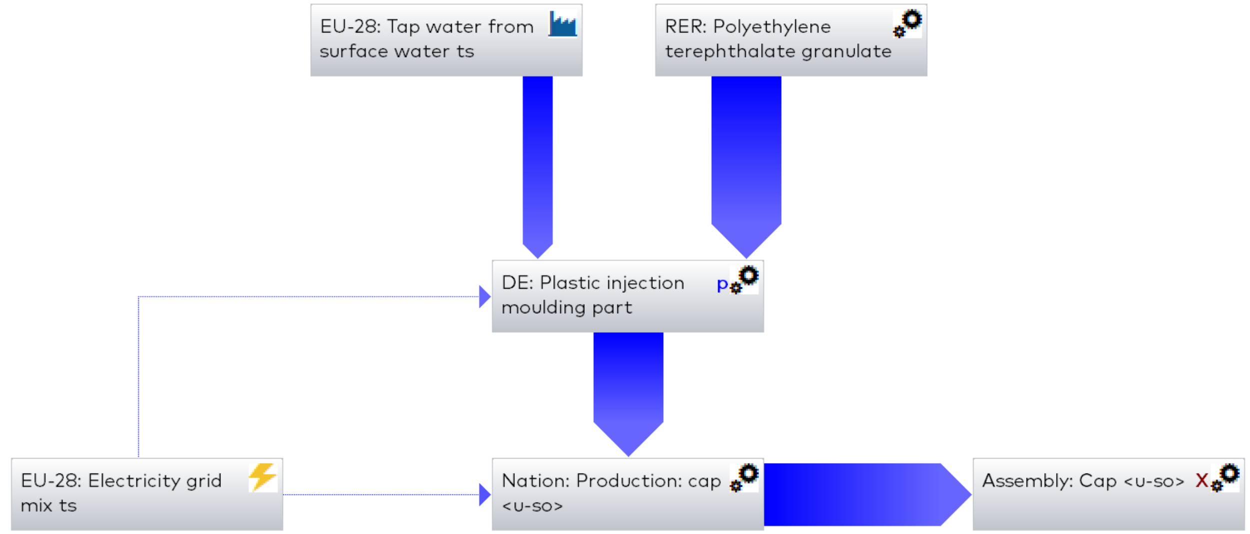


Figure 231: Production plan cap

Use reusable packaging

During the use phase of reusable packaging, the sleeve is discarded and the main container and cap are washed after each cycle. Because of this, calculations were required to determine the amount of water and energy consumed per can per cycle. Figure 232 shows the use plan of the reusable packaging. In this plan cleaning step can be found, this will be explained next.

Figure 232: Use plan reusable packaging

The inputs used in this use plan are based on ten reuse cycles. This is why the quantities in this plan are significantly higher; ten packaging's are used. The plan for cleaning reusable packaging is depicted in Figure 233.

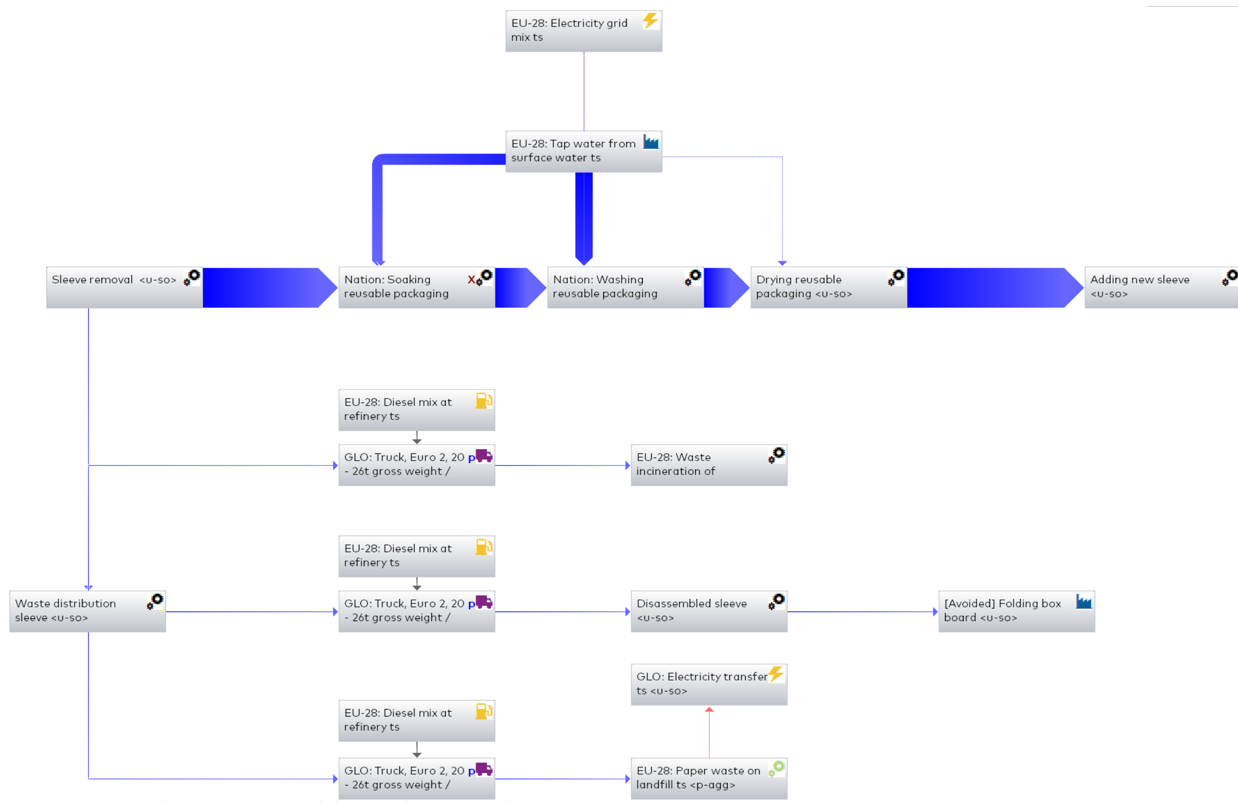


Figure 233: Cleaning reusable packaging plan

The cleaning procedure is based on online and Loop's information. The washing process exist of soaking, washing, and drying process. The duration of the soaking, washing, and drying processes is between 15 and 30 minutes. The sleeve must be removed prior to cleaning, after which it can be directly sorted for waste distribution. This is also why the waste distribution in this section is more favourable than in the disposal phase, as it is estimated that nearly every one of the sleeves removed here are recycled (90% recycling, 5% incineration, and 5% landfill).

The next step consisted of determining which number would serve as input for each step. In the process of soaking and washing, both electricity and water are used. The drying process uses only electricity. To estimate the amount of electricity used for washing, the average kWh consumption of a household dishwasher was used. The average dishwasher consumes 1.3 kWh per 1.5 hours [A36]. To determine how much energy is used per item, kWh will be divided by 56, as this is the estimated number of items that can be washed simultaneously. This results in the subsequent MJ per step:

Soaking: 0,002 MJ per piece
Washing: 0,033 MJ per piece
Drying: 0,033 MJ per piece

Next, the quantity of water used for soaking and washing will be determined. The average washing machine uses 13 litres of water per cycle, which takes approximately one hour and fifty minutes [A37]. The following amounts (in g) were calculated based on the time necessary and the number of items that can fit in the washing machine.

Soaking: 50 gram per piece
Washing: 77,4 gram per piece

For the other reuse cycle model (to determine the number of reuses required), these numbers were recalculated and modified to accommodate the number of washes required.

Disposal reusable packaging
Figure 234 shows the disposal of the reusable packaging. As previously explained, the first step in the disposal of reusable packaging involves discarding a percentage of the packaging without sorting the materials. The materials are then sorted and disposed of. To account for the amount of material that can be reused again (after recycling), avoided products were used.

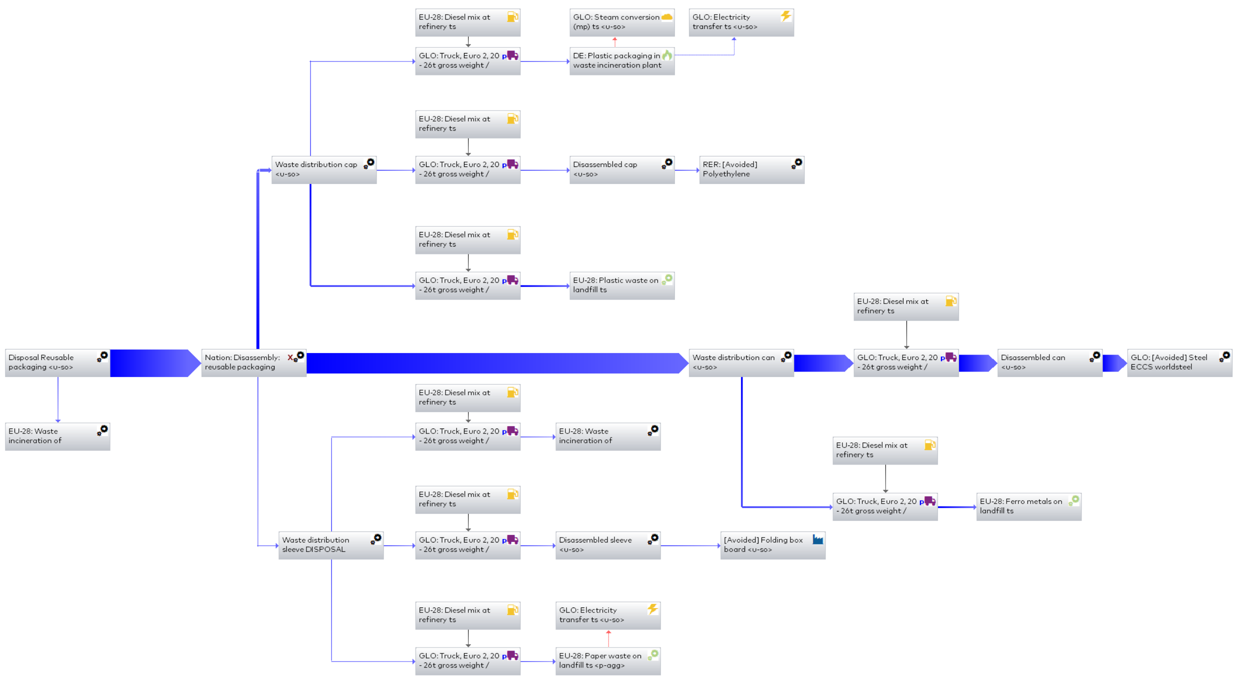


Figure 234: Disposal reusable packaging

Impact on environment

For the results of the impact assessment, the CML dashboard was utilised. First, a brief explanation of each effect will be provided [A38,A39]. The results of the comparison between reusable and single-use packaging are then presented.

Global warming potential (GWP)
The relative measure of the quantity of greenhouse gases trapped in the atmosphere. This effect is measured in terms of carbon dioxide equivalents, or CO2.

Acidification potential (AP)
The relative measure of soil and water acidification. As a result of the transformation of air pollutants into acids, the pH of rainwater and fog decreases below 5.6. This effect is measured in terms of SO2-equivalents.

Eutrophication potential (EP)
The addition of nutrients to an aquatic or terrestrial environment. This effect is measured in equivalent phosphates.

Ozone depletion potential (ODP)
The relative amount of the potential substances that can deplete ozone gas. This effect is measured in equivalent chlorofluorocarbons.

Abiotic depletion potential (ADP elements) / Fossil fuel depletion (ADP fossil)
The global reduction of nonrenewable raw materials is determined for each extraction of minerals and fossil fuels based on the remaining reserves and extraction rate. This effect is measured in equivalent of antimony (Sb) or MJ.

Freshwater aquatic eco toxicity potential (FAETP)
The potential for a chemical's toxic effect on an ecosystem, in this case freshwater, to cause biodiversity loss and/or extinction of species. This effect is expressed in terms of dichlorobenzene equivalents.

Human toxicity potential (HTP)
The amount of potentially hazardous substances released into the environment, based on their toxicity and dose potential. This effect is expressed in terms of dichlorobenzene equivalents.

Marine aquatic ecotoxicity potential (MAETP)
The potential for a chemical's toxic effect on an ecosystem, in this case the marine ecosystem, to cause biodiversity loss and/or extinction of species. This effect is expressed in terms of dichlorobenzene equivalents.

Photochemical ozone creation potential (POCP) / smog formation
The relative measure of volatile organic compounds capable of producing ground-level ozone. This effect is quantified in terms of ethene equivalents.

Terrestrial ecotoxicity potential (TETP)
The potential for a chemical's toxic effect on an ecosystem, in this case the terrestrial ecosystem, to cause biodiversity loss and/or extinction of species. This effect is expressed in terms of dichlorobenzene equivalents.

Environmental results

To calculate the results, the CML dashboard was utilised. Normalisation and weighted results will not be carried out because the results will be biased as a result. Figures 235 and 236 display the outcomes of the Gabi calculation. Multiple versions of the reusable packaging are visible in the graphs. This is done so that the break-even point for reusable packaging can be determined. In the cases of 5, 6 and 7 times reuse, the information in the models has also been modified; these results account for the various reuse scenarios.

Figure 235: Results Gabi comparison single-use vs reusable packaging (5,6,7 and 10 reuse cycles) (1/2)

Figure 236: Results Gabi comparison single-use vs reusable packaging (5,6,7 and 10 reuse cycles) (2/2)

These graphs demonstrate that reusable packaging is more environmentally friendly after seven or more reuse cycles, and in some cases even fewer reuses are required. As indicated by the global warming potential, this difference is small when the material is reused seven times, but reusing it ten times reveals a significant difference in GWP emissions. Figure 237 illustrates the division of the reusable packaging's global warming potential into life cycle stages of the reusable packaging. It is evident from this image that the use phase has a negative effect. This is due to the fact that sleeves are also disposed during this stage. The same is the case in the disposal phase.

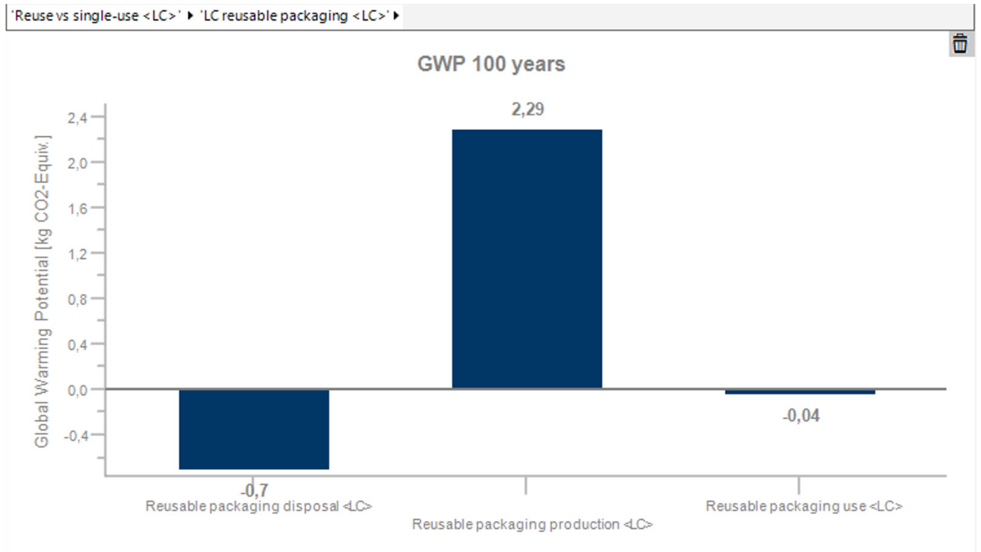


Figure 237: GWP 100 years reusable packaging (10 reuse cycles) division per life cycle

Scenario with metal cap

In addition to calculating when reusable packaging becomes more sustainable than single-use packaging, an alternative scenario has been developed. In this scenario, the packaging's cap is also constructed from Protact® PP, as opposed to the current transparent PET cap. To calculate this scenario, some estimations were required. The weight of the cap has been estimated to be 50 g netto and 57 g gross, based on a previously used excel spreadsheet. The diameter of the blank was estimated based on the width of the can plus a small overhang to allow the cap to bend.

This information has been added to the Gabi model, and the injection mould for the production of the cap has been removed. The scenario compares ten times reusing packaging to single-use packaging. Figures 238, 239 and 240 display the results.

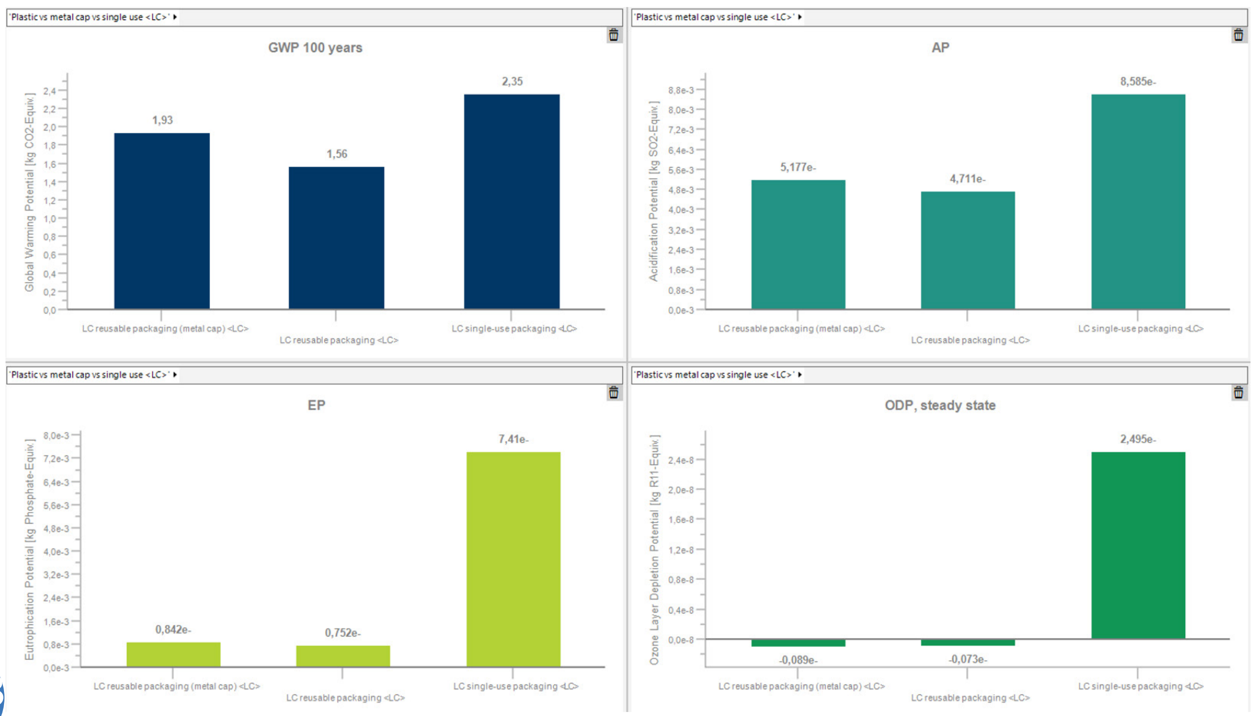


Figure 238: Results comparison single-use vs reusable vs reusable with metal cap (1/3)

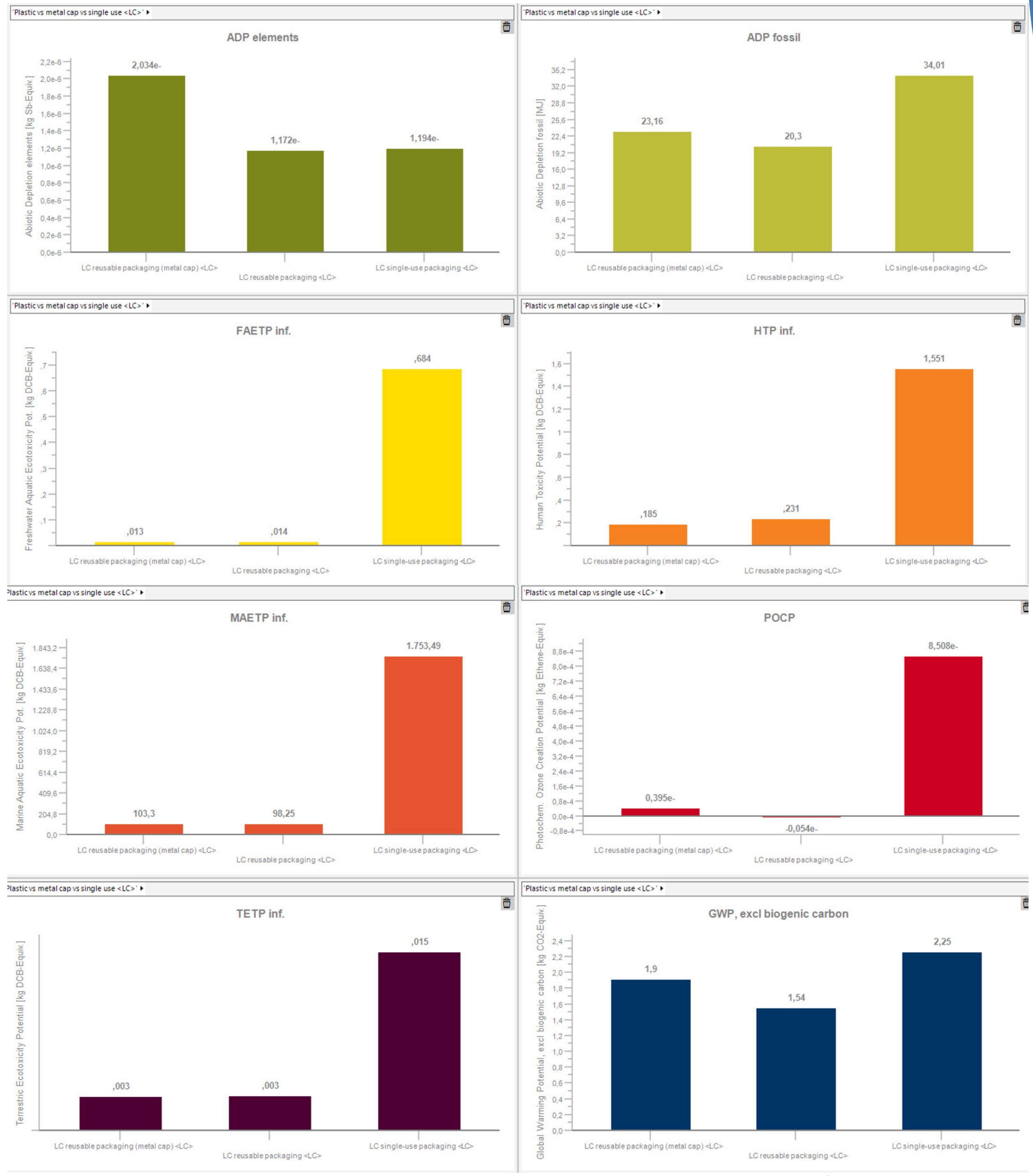


Figure 239: Results comparison single-use vs reusable vs reusable with metal cap (2/3)

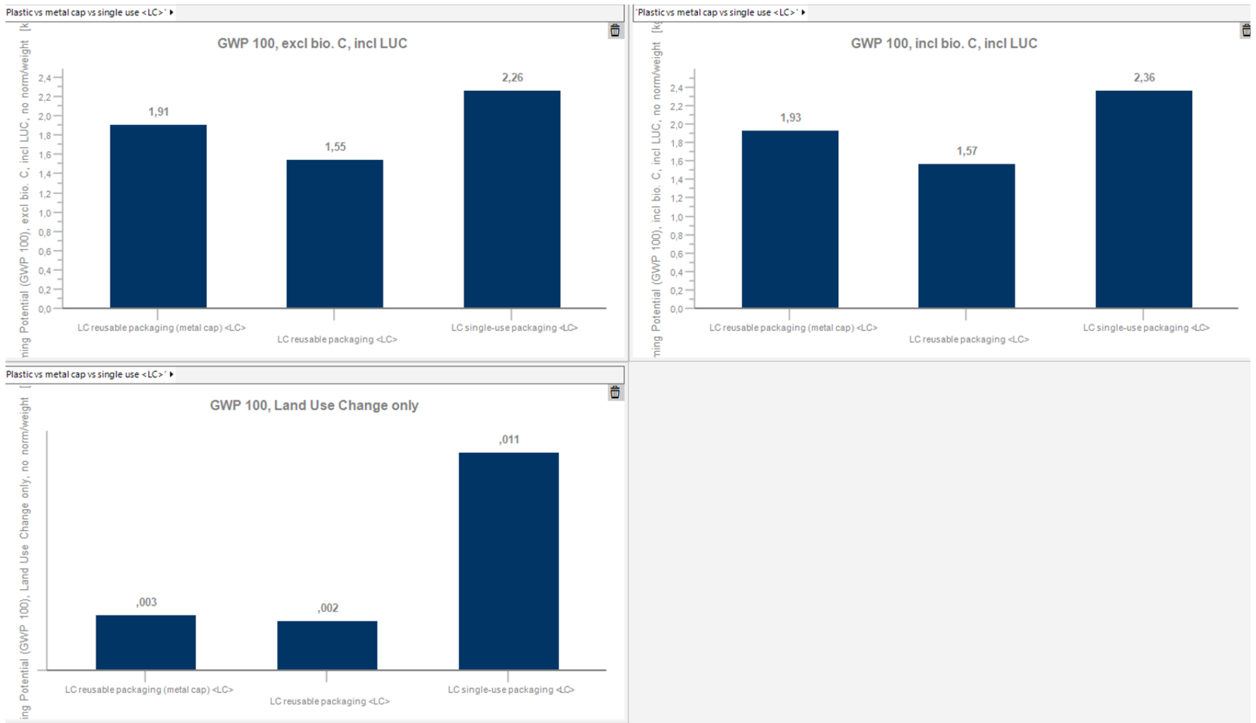


Figure 240: Results comparison single-use vs reusable vs reusable with metal cap (3/3)

These results indicate that the metal cap is less sustainable than the reusable plastic cap. To be more sustainable, the PET cap must be reused fewer times than the metal cap. Considering the global warming potential, this is evident, as shown in figure 241. It must be determined whether a PET cap made with a thicker material can withstand 10 reuse cycles. If this is not the case, this calculation must be repeated with an adjusted number for the cap required for a single life cycle of the can.

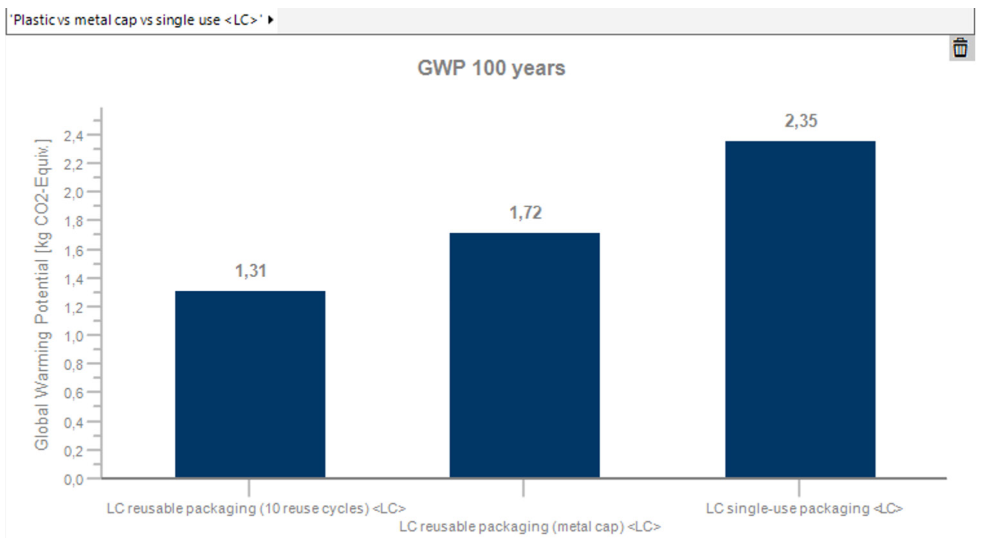


Figure 241: Global warming potential results single-use vs reuse vs reuse with metal cap

Appendix AQ: Long-term implementation strategies tool

This section describes the tool developed to calculate the long-term strategy. The tool is intended to be usable for a variety of product options. This sheet can be used for future projects and the required amounts/numbers can be modified. The sheet will describe the outcomes for each stakeholder, including the final retail price for consumers.

The Excel sheet consists of three pages. On the first page, information can be entered. This sheet provides details about single-use packaging, reusable packaging, and reuse scenarios. There is also a section for adding the profit margins per stakeholder. These profit margins were discussed with colleagues and Loop; they are depicted in figure 242. If necessary, it is also possible to increase the profit margin in the reuse scenario. During the duration of this project, they remained unchanged.

Profit margins	Single use	Reuse
Material provider	60%	
Material producer	10%	
Packaging producer	15%	
Brand owner	20%	20%
Retailer	15%	
Return/refill provider	30%	
End-of-life provider	50%	

Figure 242: Profit margins stakeholders

Single use packaging				
Compared product	Quaker Cruesli Luchtig	Calculation food costs		
Current sales price	€ 3,99	Price before retailer (- profit)	€ 3,39	
Current volume	375	Brand owner costs (- profit)	€ 2,71	
Packaging material	Folding box board & PE	Cost price food content	€ 2,35	per 375g
Estimated material costs	€ 0,06	Food price	€ 0,63	per 100g
Estimated production costs	€ 0,30	Food price	€ 2,68	per 450g (- 5% for buying more)
Total estimated cost packaging	€ 0,36			
Reusable packaging				
Volume	450	Weight steel	150	g
Packaging material	Protact PP, PET cap and folding box board sleeve	Packaging made	6667	1 ton
Calculated material costs	€ 0,26	Total tons sold	13	
Production costs	€ 0,64			
Total estimated costs	€ 0,90	Sales price ton protact	1400	euro
Sleeve costs	€ 0,14	Material and production costs protact	1260	euro
		Price per can steel	€ 0,21	

Figure 243: Information single-use and reusable packaging

In figure 243, the cost prices for single-use and reusable packaging have been added. Additionally, this is where the numbers can be modified. The prices for single-use packaging are currently estimated due to the lack of information regarding the specific material costs. The costs of reusable packaging are determined by a cost calculation. This tool also took into account the food contents, as it is possible for reusable packaging to contain more food than single-use packaging.

Total estimated products sold, single use (5 years)	500000			Recycle rate cardboard/plastic	60%
				Recycle rate steel	80%
Products sold reuse scenario				Desposit return rate	90%
Reuse amount	10				
Rejection rate after X cycles	40,00%			Calculation packaging needed	
Cans needed (purchase with addition for pool size)	85714			First time use	71429
Cans cleaned	42857			Reuse X times	42857
				Total uses	500000
Poule size calculation					
Total estimated product sold, reuse	500000	per 5 years	100000	per year	
Peak sales	1923	per	1	week	
Length peak sales	52	weeks			
Average rotation time	1	week			
Return rate	96,00%				
Minimal required pool size	100000	units			
Annual loss of packaging	96000	units			
Additional packaging needed for poule	20%				

Figure 244: Information reuse scenario

igure 244 shows the reuse scenario information. The first element that must be included is the quantity of products that will be sold, which could be per year or per five years, for instance. In this case, the average of five years was chosen because it is anticipated that the number of reusable packaging products sold will increase over time, and because each year may vary. In this instance, sales of 500.000 units per year were chosen. This is based on the assumption that 1% of the European population consumes breakfast cereal or other products daily and purchases new packaging weekly.

For the reuse scenario, the amount of reuse can be altered; in this case, the minimum amount of reuse required by Loop was used as the starting point. The rejection rate can also be altered; this rate indicates how many cans would be discarded after X reuses. This fact is used to calculate the return rate. Intriguingly, the results revealed that a decreased rejection rate has little effect on the final price paid by the consumer, but has a significant impact on the amount of steel sold. The packaging requirements for the reuse scenario have been calculated based on the reuse quantity and rejection rate. However, it is also essential to consider poule size, as this may necessitate the creation of additional packaging, and additional storage. As breakfast cereal is a product that is sold every day, it is not anticipated that the product will be sold more during a specific period of the year. It is still possible for the consumer to keep the packaging at home and use it before returning the product. As a result, an additional 20% of the required cans were added to ensure that there is always an adequate supply.

With this information, comparisons were calculated, but the excel sheet's structure will be explained before the results are presented. As shown in figure 245, the sheet has been divided into two sections: the yellow section for the non-reuse scenario and the green section for the reuse scenario. Each stakeholder has been allocated a separate box on the sheet. Based on the information gathered from the ecosystem analysis, these parties have been identified. The stakeholders on the left are also at the beginning of the reusable packaging. Figure 245 compares single-use packaging with reusable packaging employing a refill/return service. Additionally, the same sheet has been generated without a refill/return provider.

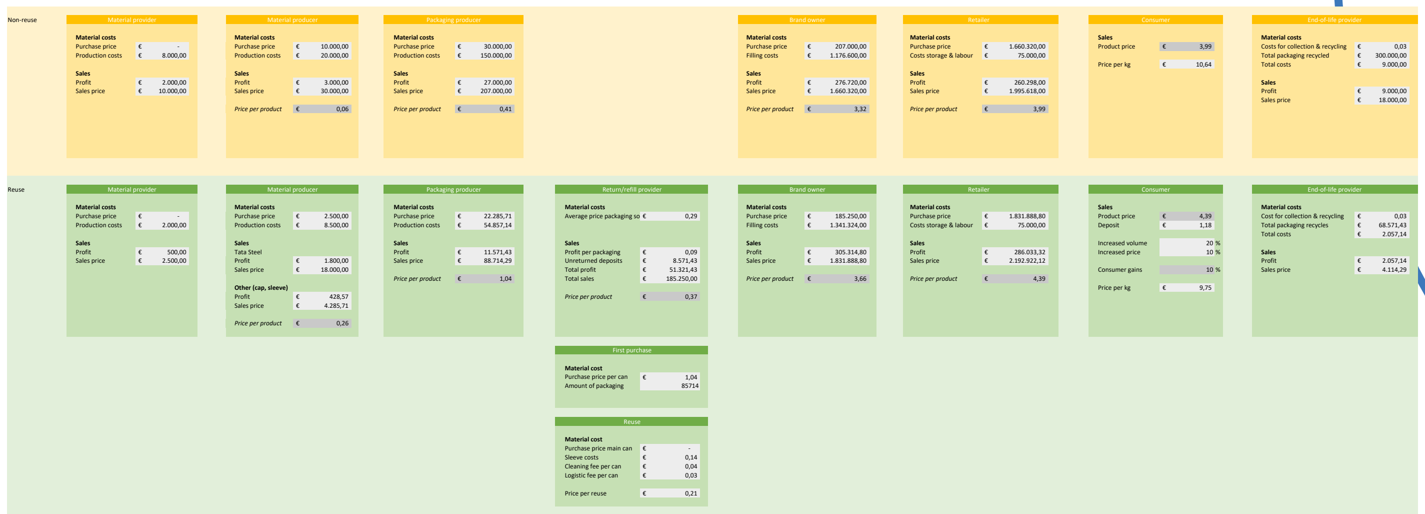


Figure 245: Setup document explanation

The first aspect that was compared was the price charged to consumers, figure 246. The consumer will always pay more for packaging that can be reused, regardless of the number of reuse cycles. Nonetheless, this is primarily due to an increase in food content. The consumer maintains a positive gain after three reuse cycles. The gain has been calculated using the additional volume (which is 20% more) minus the percentage which they would have to be pay more for the to single-use packaging.

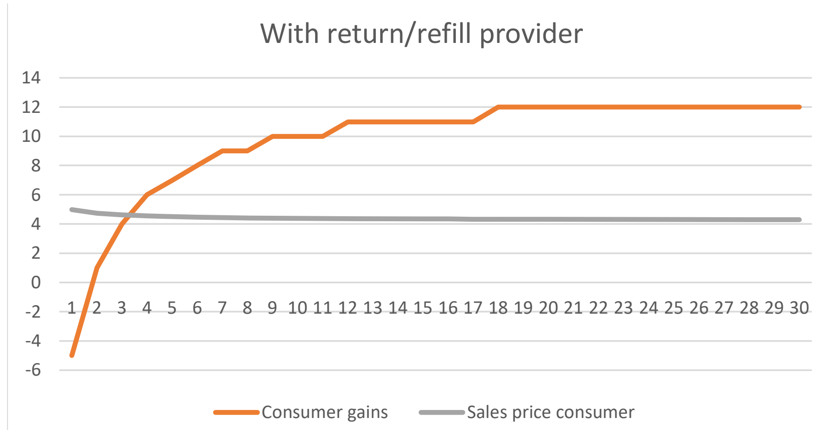


Figure 246: Consumer gains, sales price vs reuse amount (with return/refill provider)

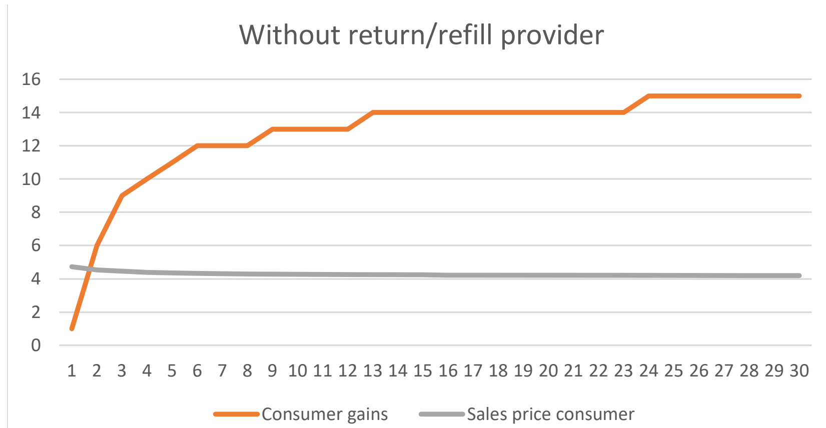


Figure 247: Consumer gains, sales price vs reuse amount (without return/refill provider)

Figure 247 shows the consumer gains without return/refill provider. This demonstrates that in both scenarios, consumers benefit from reusable packaging after three cycles. These graphs also indicate that, above a certain threshold, the sales price and the profits flat line. This is because the price of reusable packaging can only decrease as much as the costs associated with cleaning and replacing the sleeve. When the packaging is reused more often, the average cost of packaging approaches the cost of cleaning.

The price per kg was compared as another factor. As this demonstrates the consumer benefit more precisely. The comparison can be found in figure 248.

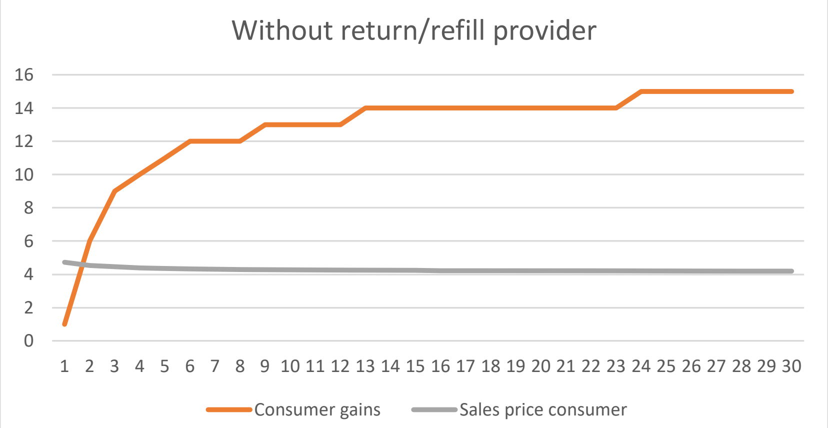


Figure 248: Consumer gains, sales price vs reuse amount (without return/refill provider)

This comparison demonstrates that it takes at least three reuse cycles for the price per kg to surpass that of single-use packaging. The numbers also indicate that the scenario in which brand owners provide cleaning and reverse logistics would be more advantageous for the consumer. As there is no other party that would also like to profit from this system.

Appendix AR: User validation setup

This appendix contains the user validation setup. This was created to assist in guiding the user validation process. The design will be validated based on the grip and the use of the easy pour. To determine whether a consumer would recognise that using the easy pour would make pouring easier. To test this, a setup plan has been developed, which will be described in this appendix.

Products used:

- 3D print of packaging and cap
- Cereal (Quaker Cruesli Luchtig)
- Bowl or cup

Setup:
The cereal will be poured into the packaging, with the cap placed on top of the packaging. A bowl will be placed next to it. When the tester enters the room, they are instructed to pour a portion of the product's contents into the bowl.

During pouring, it is essential to observe how the package is held and whether the easy pour end is utilised. The final questions, for instance, may change depending on how the tester held the packaging.

To determine the typical method of holding the packaging, a minimum of five testers are required for this validation. The desired quantity would be between 10 and 15, but it is not required because the plastic packaging is not the final version. When the actual packaging made from Protact® is used, the validation must be performed again with a larger quantity of respondents.

Appendix AS: User validation results

The validation described in the previous appendix was performed by ten Tata Steel colleagues, of whom nine pours were recorded. Unfortunately, due to NDA restrictions, the model could not be tested outside of the company. Despite the fact that not all colleagues are familiar with the design, this validation provides a good indication of how the model will be received by users.

There will be a figure for each participant that depicts how they held the packaging and utilised the easy pour. With the participants' permission, full videos are available upon request.

The first participant (Figure 249) poured the food into a small bowl with ease and immediately used the easy pour. When questioned about the size, she stated that it was large but still manageable with one hand.

Figure 249: Participant 1 user validation

The second participant was an intern at Tata Steel who had never seen the design before. Upon opening the package, she immediately noticed the indentation in the steel (easy pour) and used it to pour without any problems. The fit was also comfortable, although she did use a second hand to help hold the packaging, as seen in Figure 250.

Figure 250: Participant 2 user validation

The third participant was accustomed to the design and used the easy pour without any problems. The participant had larger hands, as shown in Figure 251, so the grip was comfortable.

Figure 251: Participant 3 user validation

The fourth participant was also familiar with the design, but he opted to pour the liquid from the opposite side without using the easy pour. Cereal spilled when pouring next to the bowl, but there was no spillage when the participant turned the packaging and used the easy pour. As can be seen in Figure 252, the grip was also satisfactory.

Figure 252: Participant 4 user validation

The fifth participant was also familiar with the design and used the easy pour without any issues. The fit was good, but the participant did notice that as the packaging became emptier, she was unable to see where she was pouring because the packaging was blocking her view, as seen in Figure 253.

Figure 253: Participant 5 user validation

The sixth participant was unfamiliar with the easy pour but was able to use it without any problems. As shown in Figure 254, the grip was also comfortable.

Figure 254: Participant 6 user validation

The seventh participant missed the easy pour and poured from the opposite side. This caused some spillage, but when the packaging was rotated to use the easy pour, no further spillage occurred. As shown in Figure 255, the grip was also ergonomic.

Figure 255: Participant 7 user validation

As shown in Figure 256, the eighth part participant used the easy pour without difficulty and had a comfortable grip.

Figure 256: Participant 8 user validation

The ninth participant also used the easy pour without any issues, and the grip was comfortable, as shown in Figure 257

Figure 257: Participant 9 user validation

The final participant used the easy pour and was also familiar with the design. The grip was good, and there were no problems when pouring the contents.

In conclusion, the packaging's grip was found to be comfortable and suitable for one-handed use. The issue of grip was resolved by reducing the diameter of the packaging's underside. In addition, the majority of participants (8 out of 10) used the easy pour side of the packaging, resulting in no spillage. When using the opposite side, however, spillage was observed. One limitation to be aware of is that part of the participants found it difficult to see where they were pouring as the packaging became emptier. Overall, these results indicate that the easy-pour design is effective at reducing spillage and enhancing the user experience, while also highlighting the need to address visibility issues when the packaging is nearly empty.

Appendix AT: Planning project

In this appendix the planning of the project can be found. The planning shown is version 4 of the planning. The adjustments made to this planning occurred during the project, as soon as more time was required material research. Figure 258 shows the planning.

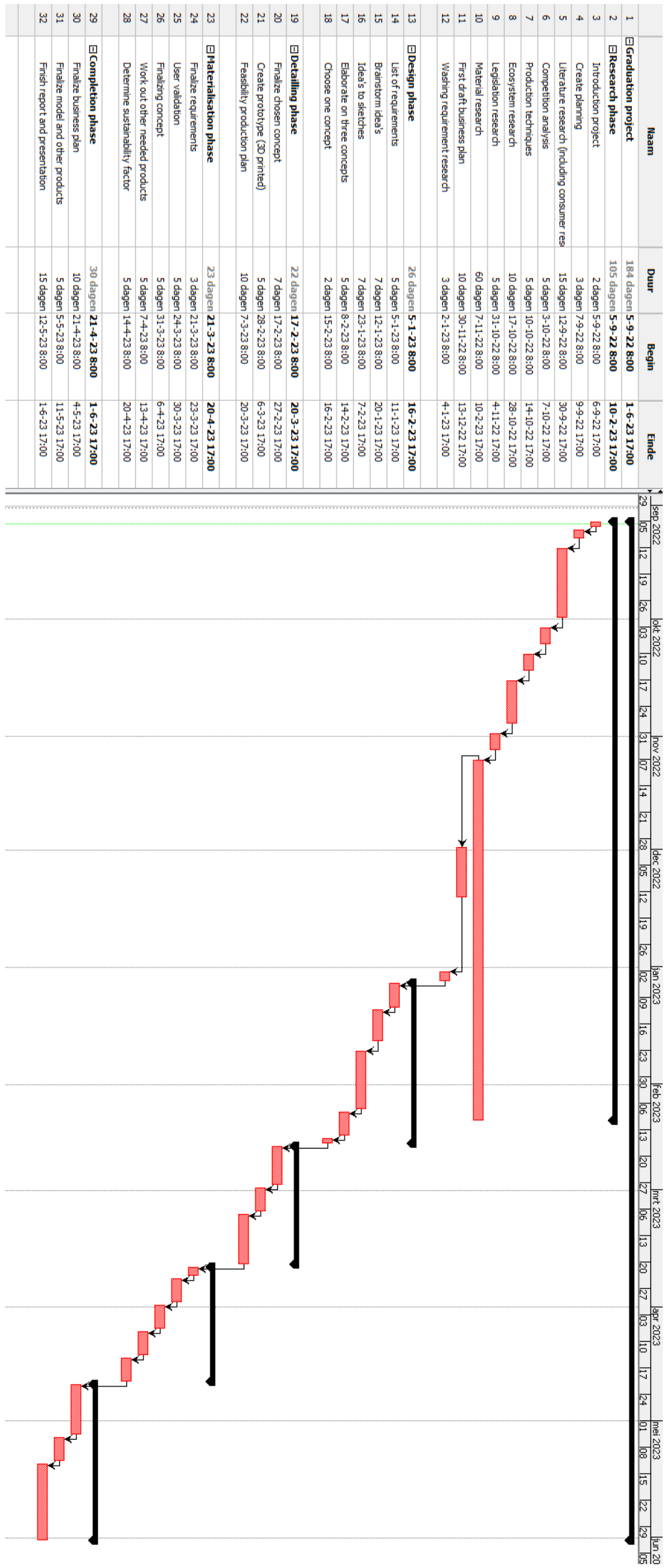


Figure 258: Planning project v.4