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BOKS:

A Waste Free Insulative Packaging Concept to Transport Perishable Goods for Ecommerce

MASTER THESIS

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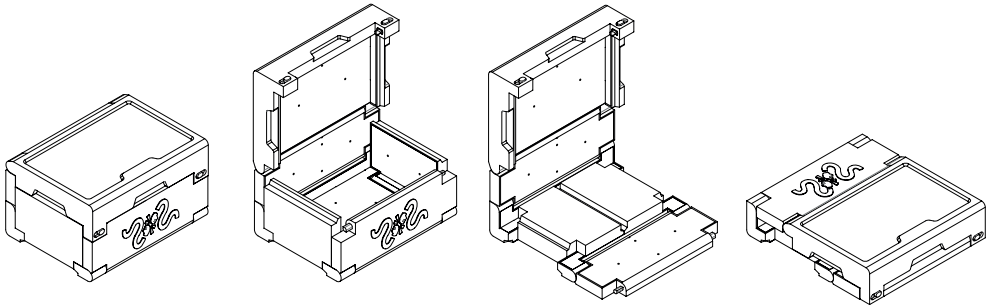
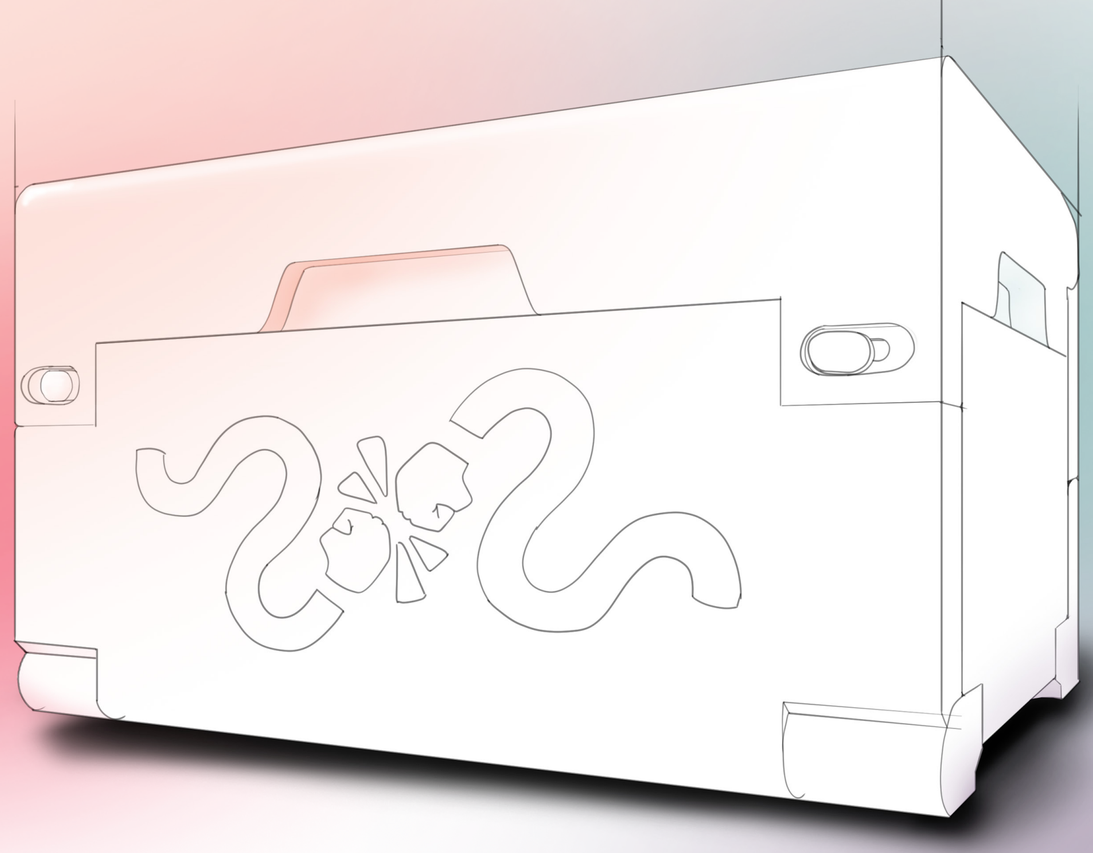


The Courier, Express and Parcel market (CEP) in the Netherlands causes 85.000 tons of single use packaging to be turned into waste on a yearly basis.

(Thuiswinkel.org & Kennis instituut duurzaam verpakken, 2020)

This number will rise as e-commerce is projected to grow 10% annually, by 2030 the CEP market will be 2.59 times its size.

(Topsector Logistiek, 2020)



Let's BOKS

for a waste free future

Dear reader,

The time has come to face the impact we cause on the only planet we have. Our current consumption rate and quest for the latest innovations cause products to be discarded faster and faster. Now, more than ever, we need to act upon our behaviour and start to think long term. As a species we might regard ourselves to be superior, however this is a delusion which becomes painfully clear with the current pandemic and climate change disasters such as floods and forest fires.

The time has come to start living in symbiosis with nature. Nature thrives in ecosystems where resources circulate from one source to the other. Here the whole is greater than the sum of its parts. If we are truly as great as we suggest, successfully switching to this symbiosis would be one of the greatest challenges to prove that.

In this graduation project I tried to lay out the fundament of such a system for ecommerce packaging. Insights from this project could contribute to one of the building blocks towards a circular economy. This thesis is the final result of my last contribution being a student of the Delft University of Technology.

I would like to thank my supervisors for always challenging me to get the most out of this project. Your support helped me get through the tougher times during this project.

Ruud, your enthusiasm sparked me since our first meeting. Your experience as a designer and chair made me feel comfortable even though we never met in public!

Matthijs, your empathic listening takes away barriers and made me feel understood. Your critical entrepreneurial mindset worked refreshingly and was a great addition to my graduation project. Your expertise is valuable to the faculty of Industrial design engineering!

I would also like to thank my parents.
Mom and dad, thank you for always supporting me. Without your help this achievement would not have been possible.

Furthermore, I would like to thank the SVM for granting me the Packaging and Environment Scholarship. This scholarship helped me build and test the design, which raised the overall quality of the project. I would also like to thank all experts and customers for their time and knowledge.

Last note, this report is written in pyramid style. This means that conclusions are presented first and underlying analysis is presented after that to support these conclusions. As a result this report contains 4 main layers. At the start of each layer the pyramid icon is shown to guide you while reading.

Thank you for reading this report, I hope it can be a source of inspiration for you.

Gys Gillissen

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“So excellent we are as humans in production and consumption that in the recent past we have tended to overlook the large-scale consequences of our material consumption.

These days we are becoming aware of the damage we cause, and we are gradually learning to be more careful.”

~Siem Haffmans, Products that flow

BOKS

BOKS is an insulative reusable packaging for ecommerce. It assists webshops to transport cooled perishable goods directly to their customers without creating waste. BOKS is designed to replace single use packaging such as cardboard and non recyclable packaging such as Polystyrene (EPS). By making use of passive cooling no additional energy input is required to keep the products cooled. With an organic hemp insulation layer in combination with the right amount of coolants BOKS is capable of steadily keeping frozen products under 5 °C for 36 hours. At a competitive price point BOKS has the potential to become a sustainable contender for current ecommerce packaging solutions.

Order perishable goods online

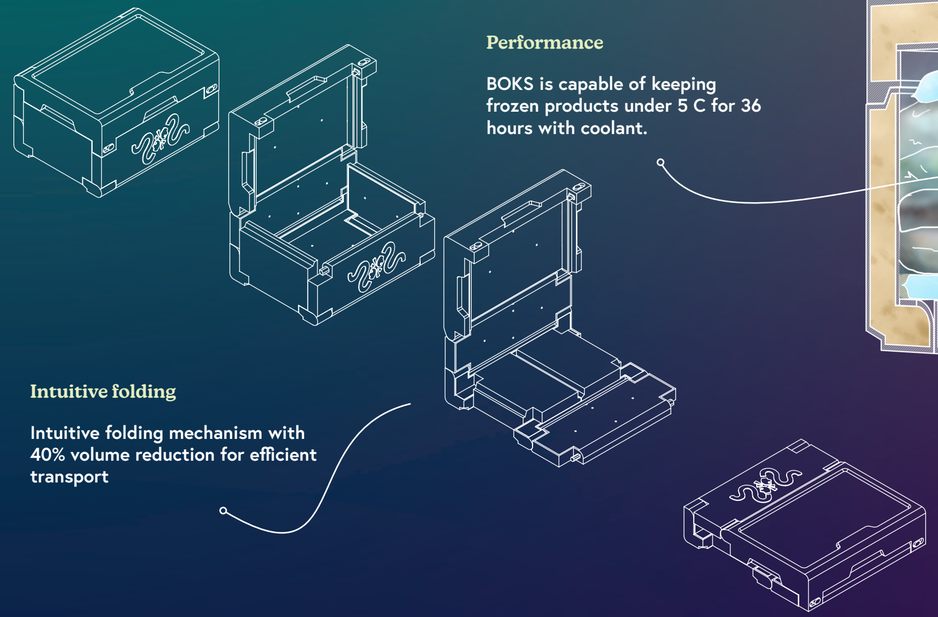
BOKS is designed to facilitate webshops in delivering cooled perishable goods directly to their customers.

Performance

BOKS is capable of keeping frozen products under 5 C for 36 hours with coolant.

Intuitive folding

Intuitive folding mechanism with 40% volume reduction for efficient transport

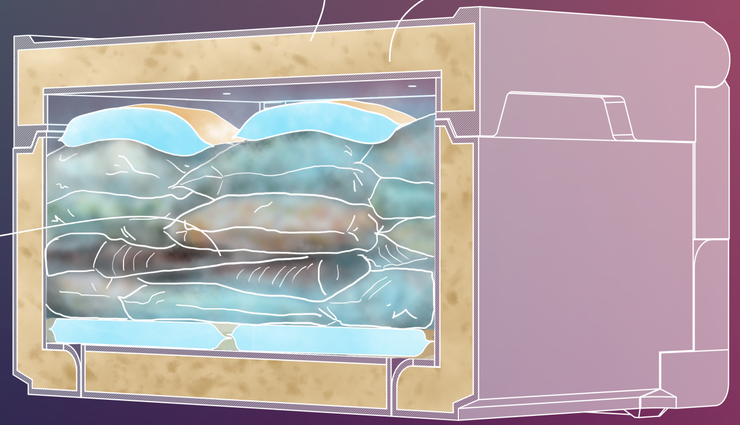


Insulation

25 mm organic hemp fiber insulation layer sourced in the Netherlands.

Volume

The inside volume is 33.4 x 23.4 x 16.5.



Designed for contin-use

BOKS is designed to be reused for up to 100 times.

Flowing in a circular system

BOKS is designed for a system which incentivises all stakeholders to keep it flowing.

Ecommerce without waste

BOKS does not create material waste compared to conventional ecommerce packaging.

BOKS compared to single use cardboard

	Cardboard box + insulation liner	BOKS
Weight [kg]	0.4	2.9
Cooling time [hr]	12 - 24	36
Lifetime [trips]	1	100
Price [€]	3.00	3.19
Material weight [kg / 100 trips]	40.0	2.9 (saves 37.1 kg)
CO2 emissions [kg / 100 trips]	54.1	17.1 (saves 68.32%)

Table 1: Impact of flow time modifications

1. Summary

Ecommerce without waste

The Courier, Express and Parcel market (CEP) in the Netherlands causes 85.000 tons of single use packaging to be turned into waste on a yearly basis (Thuiswinkel.org & Kennis instituut duurzaam verpakken, 2020). This combined with an annual projected growth of 10% in online orders urges society to rethink ecommerce packaging (Topsector Logistiek, 2020).

This graduation project is performed for Goodcase. The startup aims to accelerate the shift towards a sustainable diet by offering sustainable foods from Dutch startups directly to the customer. The goal of this project is to find the most sustainable way of transporting perishable goods for Goodcase.

BOKS is the frontrunner in a new era of packaging in ecommerce. It is part of a system where material resources are circulating within a closed loop: the circular economy. This paradigm puts emphasis on designing out waste. Switching from single use to reusables fits in this philosophy. This switch is critical to sustainably deal with the resources our planet has to offer. Switching to BOKS prevents the creation of excessive waste and therefore decreases the environmental impact of insulative ecommerce packaging.

Reliable cooling

BOKS is specifically designed to assist webshops transporting perishable goods directly to their customers. These foods need to stay under 5 °C during transport. The optimal configuration of BOKS is designed using a parametric thermodynamic model.The walls of BOKS are filled with a 25 mm organic hemp layer. The insulative principle of hemp is similar to wool; small air pockets in the material prevent heat from transferring through. Due to this insulation layer the products stay cooled consistently for up to 36 Hours. Within this timeframe two delivery moments can be achieved with a success rate of 99.9%. This is what makes BOKS the most reliable way of sending cooled perishable goods!

Sustainable alternative

BOKS is designed for contin-use, it should flow from stakeholder to stakeholder. A fast track life cycle analysis model is used to minimize its environmental impact. It could be reused up to 100 times and therefore saves up to 37.1 kg of single use packaging, insulation and buffer materials. The folding mechanism results in a 40% volume reduction which makes BOKS efficient in logistics and more manageable to handle for its users. The CO_2 emissions per trip are 68.32% less compared to a single use cardboard box. This in combination with 40% recycled materials in the outer layer, BOKS is a sustainable contender for transporting perishable goods!

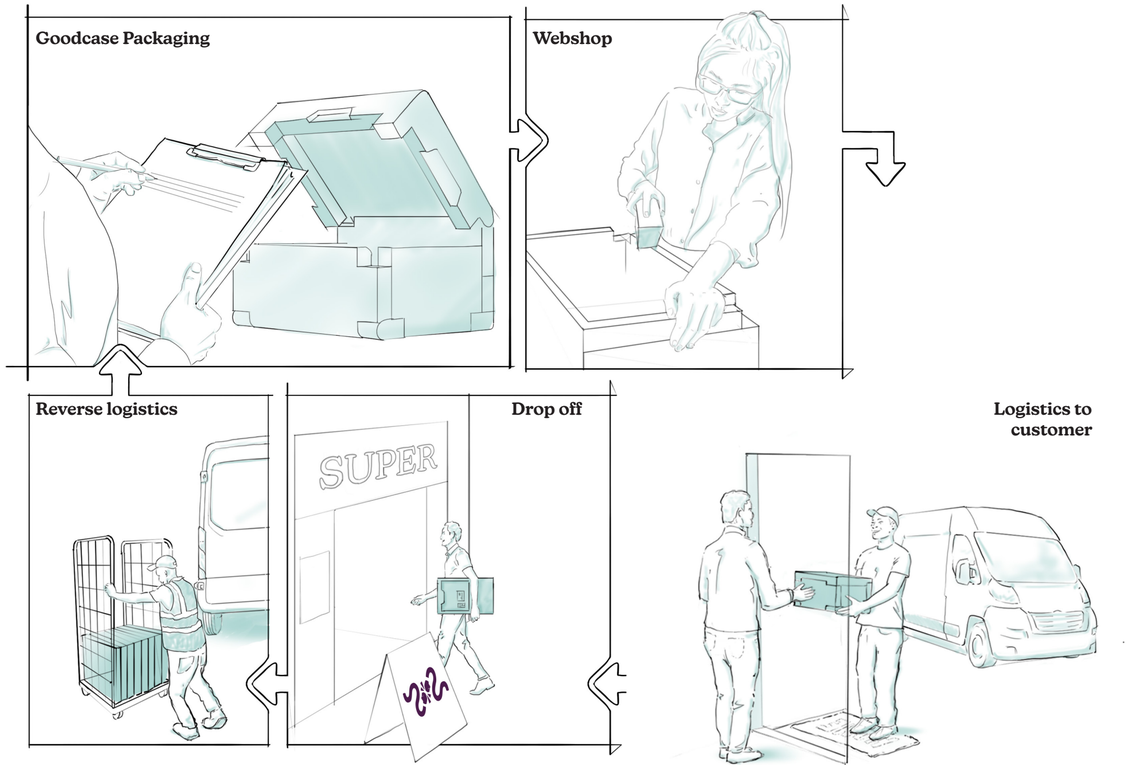
Circular reuse system

The flowing of BOKS generates revenue for Goodcase Packaging. Based on a parametric financial model a competitive selling price of €3.19 could be achieved. The result is the system described in figure 1. BOKS flows from Goodcase Packaging to the webshop, where it is subsequently packed and delivered to the logistics party. They deliver it directly to the customer, who returns it at their local supermarket or drop-off point. From there on, the BOKSES are shipped back to Goodcase Packaging in bulk. At Goodcase Packaging they are cleaned and inspected before sending them out for their next loop!

BOKS is designed with all aforementioned stakeholders in mind. It was found that a reward program is crucial to incentivise each stakeholder to keep passing BOKS on. This reward program aims to actively involve both the webshop and the customer. Webshops are rewarded with a discount for a higher return rate. The customers are rewarded with a digital token which they can redeem in a marketplace with all connected webshops.

BOKS has been tested and proven to perform up to most of the requirements. However, further development is required to make the concept of BOKS ready to be used in the real environment.

Figure 1: System and stakeholders



Final Design

A detailed display of all features of the solution

2.1 Introduction

The Courier, Express and Parcel market (CEP) in the Netherlands causes 85.000 tons of single use packaging to be turned into waste on a yearly basis (Thuiswinkel.org & Kennis instituut duurzaam verpakken, 2020). This number will rise as the CEP market is projected to grow 10% annually, by 2030 the CEP market will be 2.59 times its size. Online orders for groceries have also shown a steep growth of 25% since the beginning of 2020 (Topsector Logistiek, 2020), as described in chapter 3.2. Compared to regular parcels, the excess of insulation and protective packaging is what makes this sector even more wasteful. The amount of waste created combined with the projected growth urges society to rethink ecommerce packaging.

The goal of this project is to find the most sustainable way of transporting perishable goods for Goodcase. The scope is narrowed down to design a waste free solution for Goodcase and online food suppliers, see chapter 3.1. The result is an ecosystem where perishable goods are transported in reusable containers. In this vision the system and the product are interconnected; they can not be designed individually. Therefore, both the system and product are in the scope of this project. In order to deal with this complex problem space, a specific approach is used which is described in chapter 2.2.

BOKS is designed based on three individual parametric models. Based on their output the design is optimized to address the problem on a system level, product level and from a business perspective, see figure 2:

Firstly, a shift towards a circular system is described to sustainably deal with the resources our planet offers (Park & Chertow, 2014, p. 46). Current single use packaging operates in the take-make-waste system, this paradigm describes a linear flow where resources lose their value relatively quick. Contrarily, a circular paradigm describes the flowing of resources among stakeholders within a closed ecosystem (Ellen McArthur Foundation, 2019). Circular resources retain their value longer through the principles of reducing, reusing and recycling (Haffmans & Gelder, 2020). A **fast track Life cycle analysis (LCA) tool** is used to find the right balance to minimize the impact of BOKS. The solution to this challenge is described in chapter 2.5.

Secondly, a shift towards reusable insulation materials with minimal environmental impact is required. A **thermodynamic model** is designed to find the right balance for optimal performance. The insulation layer should keep the goods cooled up to a point where it arrives at the customer, see chapter 2.3. Current insulation materials are often discarded directly after usage, while still being usable. On top of that, popular insulation materials such as EPS, PU and PE-Foam are difficult and expensive to recycle (Dieckmann et al., 2019, p. 100360). Resulting in the fact that around 80% of EPS produced in the USA is currently landfilled (Chandra & Kohn, 2016). Switching towards organic insulation materials and making sure that they can be reused to their full potential decreases the environmental impact.

Lastly, the proposed solution is designed to become an asset for Goodcase. It incentivises stakeholders to let the product flow from one stakeholder to the other, see chapter 2.4. Running the operations requires collaboration between multiple parties such as webshops, logistics and maintenance. A **financial model** is designed to find the right balance in order to keep the costs low and show potential to generate revenue for Goodcase, see chapter 2.6.

Additional challenges that have been addressed during this project are described in chapter 2.7. In chapter 2.8 the program of requirements is presented and validated. Although BOKS has proven to be able to function conform to the requirements, there are recommendations to further improve the functioning of the concept, see chapter 2.9. The design process is described in chapter 3.11.

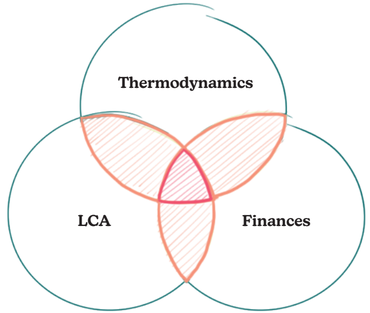


Figure 2: Overview of parametric models and overlapping objectives.

2.2 Project Approach

Applying structure

The problem space is complex, since both the product and the system are interconnected within their context. Therefore this project is structured with **design challenges (DC)** and **design fundamentals (DF).**

Design challenges describe the problems concerning the functioning of the product and the system. Design fundamentals describe the context the product and the system need to operate in.

The combination of these self-developed tools allow one to apply focus on solving individual problems while keeping in mind its context.

Design Fundamentals

Make sure the product fits in the context

Conventional

The conventional design process is characterized by an elaborate analysis which describes the context the product will operate in, see figure 3. This context can be complex because of multidimensional characteristics. The analysis phase enables a designer to have an elaborate understanding of the context.

However, the understanding remains locked in the head of a designer or disappears in the program of requirements. The vastness of research makes it easy to overlook all separate findings during the design phase. In addition, due to the lack of concreteness there is little way to backtrack the origin of ideas.

During testing the context suddenly becomes concrete. Then it could become apparent that the design does not fit in the context optimally. Which results in the need for a revision of the analysis and design in order to make it better fit.

Fundamental

Aiming to smoothen this timely process, the fundamentals are a tool designed to make the context concrete and tangible early on in the design process.

The most important context factors are combined into a list of tangible requirements. With this list the quality of ideas can be continuously monitored during the design phase, so non-fitting solutions have no chance to slip in the design. In addition it allows ideas to be easily backtrackable and it prevents unwanted surprises during testing.

The way the fundamentals are translated into the final design is described in chapter 2.7. An elaborate description and evaluation with in addition the pros and cons of this method, can be found in appendix A.

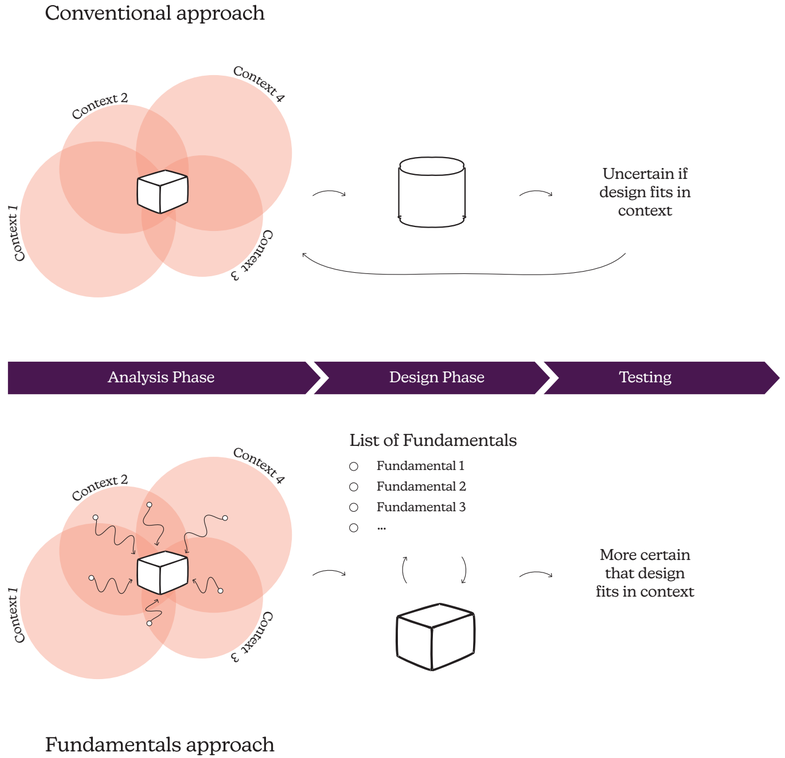


Figure 3: Design Fundamentals explained

Design Fundamentals of a Circular System

In this section the Design fundamentals are elaborated.

Design for Contin-use

This fundamental describes characteristics which make the product fit to be reused by different consumers in different environments (Haffmans & Gelder, 2020). Single use products show almost instant value drops after consumption. As a result these products become waste which in the best scenario will be recycled (red line, figure 4). On the other hand, contin-use products are not designed to become waste, see chapter 3.5. Choosing durable materials makes the product last longer, see chapter 3.6. Contin-use products are characterized to be passed on to another user once they are no longer valuable to them. As a result these products keep their value at each individual moment of consumption (blue line, figure 4). Therefore they are able to provide value to different consumers for a longer time without depleting material resources.

Design for flow

This fundamental describes products which are meant to be passed from one stakeholder to another. Incentivising each user to pass on the product to the next user, see chapter 3.7. Design for flow indicates that the product should keep moving. To prevent the consumer from keeping the product, the value needs to drop below a certain level (reward value, figure 4). This reward incentivises the consumer to pass the box on to the next stakeholder in the loop. The reward differs drastically based on the product, the market and the target group, so this requires a custom approach, see Appendix B.

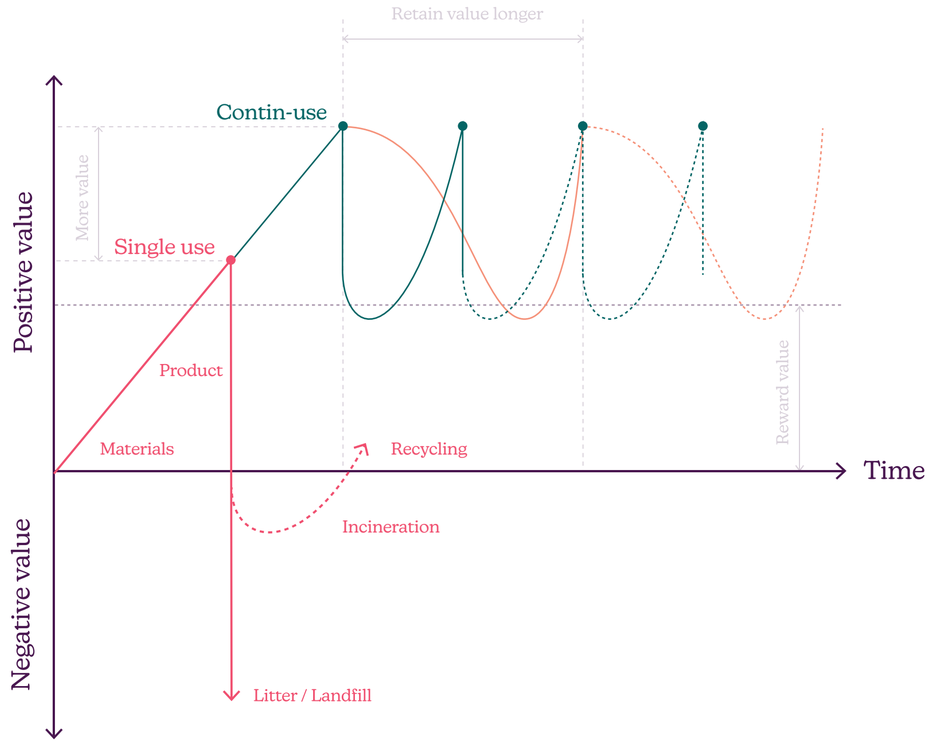


Figure 4: model retrieved from: Products that Flow, Haffmans & Gelder, 2020, retrieved from p.14. Modifications have been applied to improve the fit with the project.

Design for repairability

This fundamental focuses on repairs which need to be performed on the product. Designing the product with (dis-)assembly in mind and making use of modular parts with universal connections increases the repairability drastically, see chapter 2.7.

Design for low maintenance

Another maintenance which needs to be performed is cleaning. Especially since the inside of the container will be in contact with (packaged) foods, it is important that it is easily cleanable. This prevents dirt buildup and undesired odours. The selected material needs to be durable under these conditions.

2.3 DC1 : Performance

Optimize the passive cooling to keep perishable goods reliably within the right temperature range during transport up to the point when it arrives at the customer. Functioning needs to be guaranteed all year around, including hot summer days.

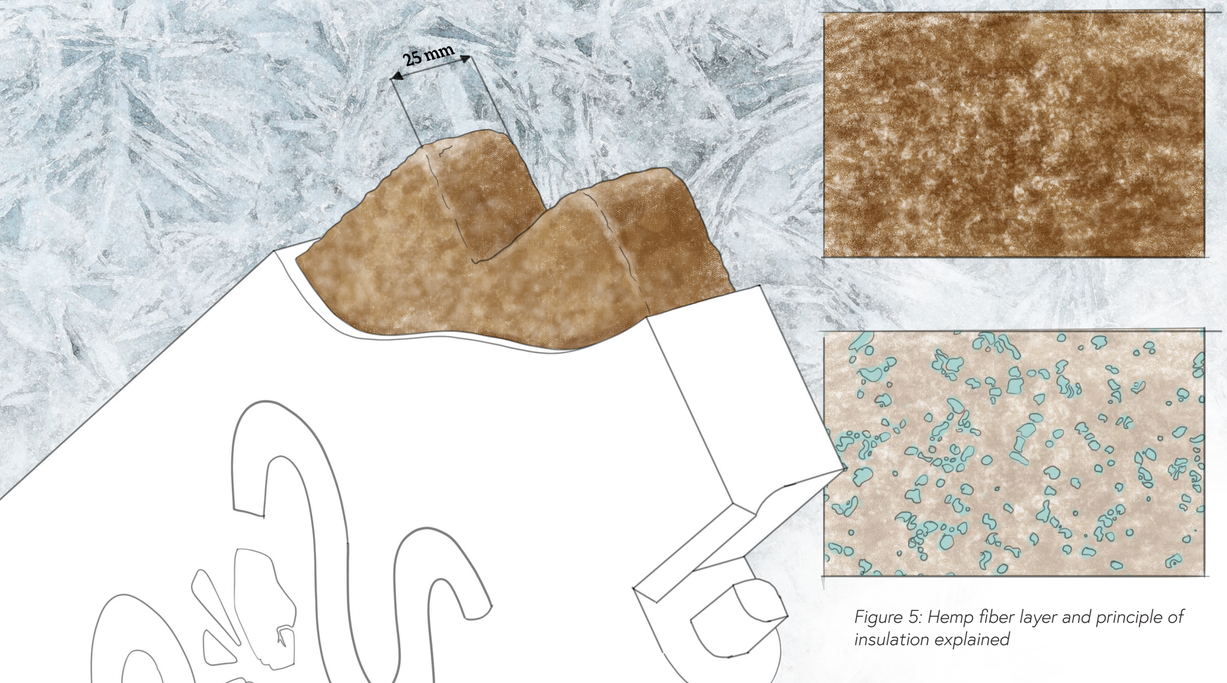


Figure 5: Hemp fiber layer and principle of insulation explained

Passive cooling

BOKS makes use of passive cooling, this means that no additional energy input is required. Instead a specific amount of coolant in combination with an insulation layer which prevents the passage of heat from one conductor to another is used (Miriam Webster, z.d.). The amount of coolant can be altered based on the environmental temperature, the weight and the type of food.

The required cooling time is 36 hours which has been concluded from the logistic journey map in chapter 3.3. Within this timeframe the logistics carrier will be able to have at least two delivery moments with a customer. The first delivery moment has a 98% success rate and can be achieved within 12 hours.

The maximum temperature depends on the type of products that are transported. Legal temperature thresholds for meat products state that it must not surpass 5 °C (Food and Drug Association, 2021). Product deterioration is accelerated during exposure to temperatures above these limits (Dieckmann et al., 2019, p. 100360).

Insulation material

From the material analysis in chapter 3.6 it has been concluded that the best fitting insulation material is hemp. Its principle of insulation is similar to wool and feathers, which originates from nature. A dense network of fibers creates a large amount of small air pockets, these pockets prevent convective heat flow, see figure 5. The fibers themselves have a low thermal conductivity, which prevents heat from passing between molecules within a solid material. Its structure and its properties make hemp an excellent natural insulation material, this has also been concluded from testing described in chapter 3.8 and appendix C.

EPS (styrofoam) is currently the predominantly used and best performing insulator. However due to its poor and expensive recyclability most of EPS ends up as landfill causing damage to the environment. Hemp is a completely organic material which will decompose and enriches the environment in the process as described in chapter 3.6.

The downside is that the thermal conductivity of hemp is lower compared to EPS, hence more material thickness is required for a similar performance. Conclusions have been drawn making use of the prototype and thermodynamic model described in chapter 3.11 and appendix D. It was found that a constant environmental temperature of 21 °C would require 2.5 cm of hemp and 5 cooling packs in order to keep 3kg of perishable goods under 5 °C for a minimum of 37 hours.

In addition hemp lacks the structural properties which raises the need for an encapsulating case material. Polypropylene (PP) with 40% recycled content was found to be the best performing material. This is a widely used material for packaging and containers, its mechanical and impact properties make PP a durable material suited for logistics, see chapter 3.6.

2.4 DC2 : Reuse

Create a reusable solution with a viable business model which creates incentive for all stakeholders to keep the product flowing. To set up the system, collaborations with other parties like logistics, maintenance and service providers need to be explored.

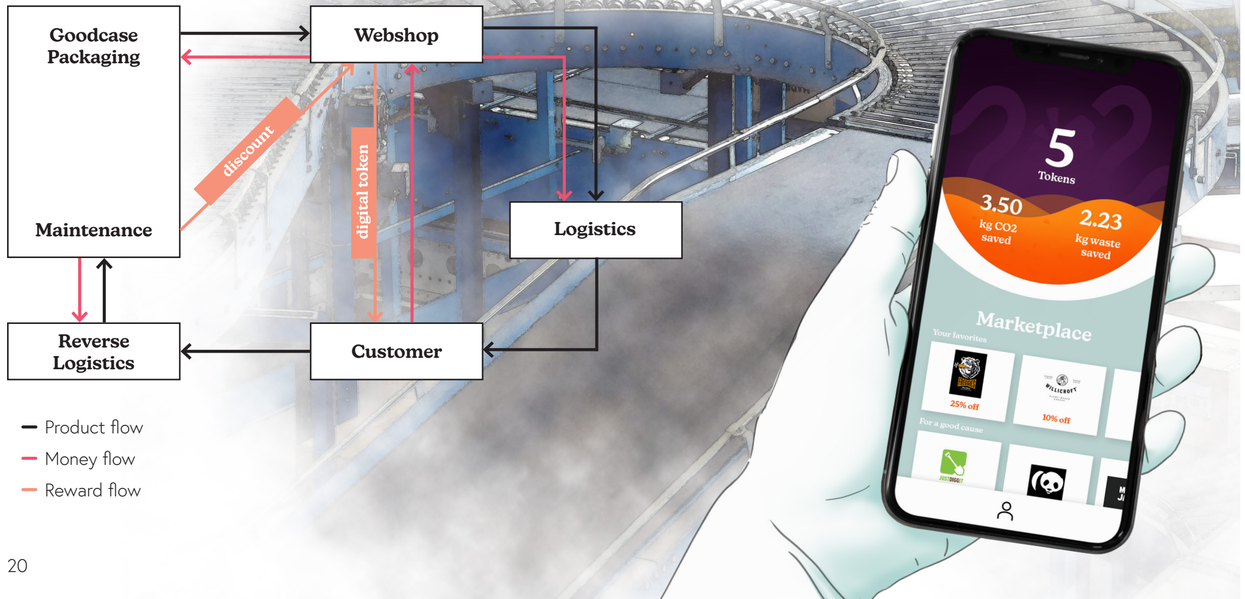


Figure 6: BOKS flow and mockup of marketplace

Benefits of a reuse system

Switching to reusables has the potential to be beneficial from both an environmental and business perspective. With the introduction of reusable materials, the need for virgin materials is reduced and the potential rises to reduce the environmental footprint of the used materials (Coelho et al., 2020).

A forecast by The Ellen MacArthur Foundation (2020) states that by converting only 20% of packaging to reusable systems could create a $10+ billion opportunity (Ellen MacArthur Foundation, 2020). Besides this, they state it could provide additional benefits such as improved brand loyalty, mass customization and gathering high quality user insights, see chapter 3.5.

Reusables could optimise operations and eventually save costs (Ellen MacArthur Foundation, 2020). These benefits have to be considered while designing the reuse system while also keeping in mind the stakeholders described in chapter 3.4, the industry, intended scale and geographical location (Fashion For Good, 2021).

Collaborations

Within one loop, BOKS has many touchpoints with a diverse set of stakeholders. Instead of Goodcase packaging operating the whole loop, an ecosystem is proposed with operating stakeholders. Collaborations between logistics, maintenance providers and data analytics form the basis of this ecosystem. Each stakeholder is responsible for operations within their expertise. This allows them to extend their reach and benefit from each other's networks.

Performance rewards

The system describes the flow of BOKSES between stakeholders. From the analysis in chapter 3.4 it was concluded that a reward system needs to be present in order to incentivise all stakeholders to keep the product flowing. This reward system focuses mostly on the customer, as their behaviour needs to change the most. This is elaborated in the circular business model in chapter 3.7. With every returned box, the customer receives a digital token. This token can be redeemed at the digital marketplace. All associated webshops are connected to this marketplace. For them, this could be a way of acquiring new customers.

Webshops can decide themselves what reward the digital token should represent in their webshop. Involving the webshop in the reward scheme allows them to adapt the reward to their individual customers' needs as they know their audience the best. In addition, it incentivises the webshop to clearly communicate the intended behaviour of the customer with BOKS.

The more boxes returned from the customer to Goodcase packaging, the higher the discount webshops will receive as described in the cost analysis in chapter 3.9. This incentivises both the webshop and the customer to keep the product flowing.
This system shows similarities to circular alternatives described in chapter 3.7. However, the system needs to be validated with actual stakeholders. Especially for determining the rewards, which might differ per customer segment and webshop. The value of the reward is crucial for flow as described in figure 6. Validation is elaborated in the concerns and improvements in chapter 2.9.

2.5 DC3 : Sustainable

Minimize environmental impact over the entire lifecycle of the product. Educate and inspire consumers to learn about the environmental impact of packaging through materials, data and stories.

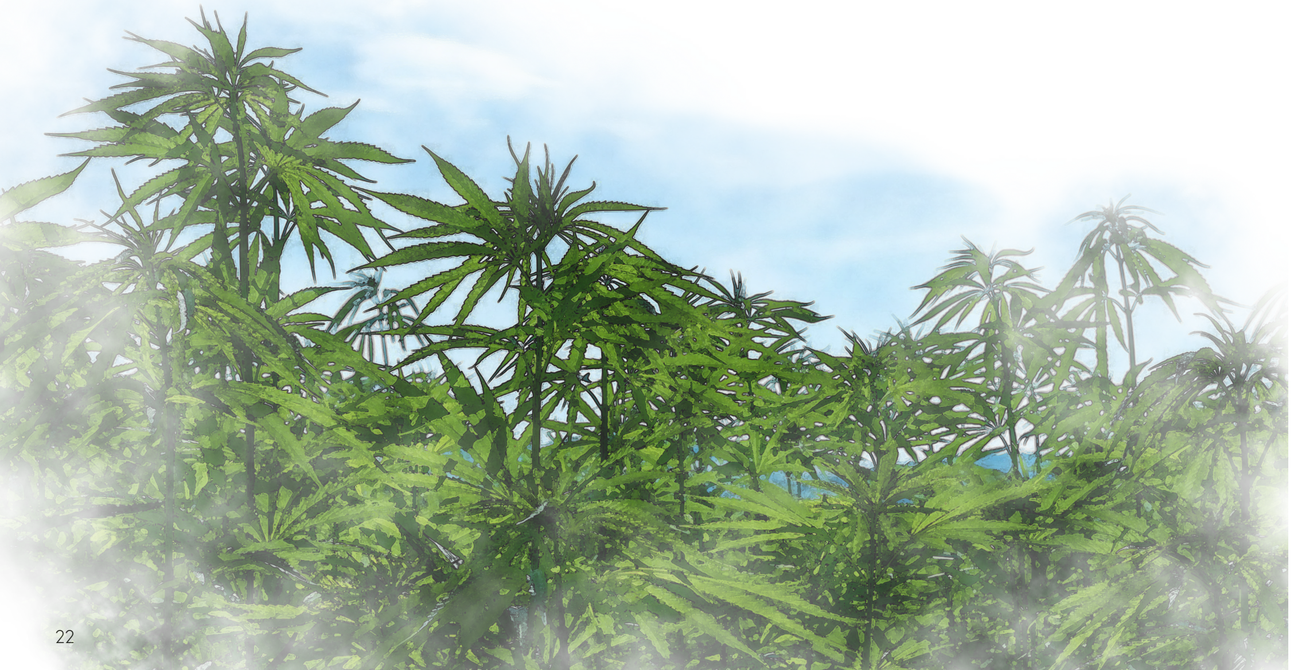


Figure 7: Hemp field

Reusables

The flow of reusables has the potential to generate less CO2 emissions compared to single use alternatives. This has been concluded from the fast track life cycle analysis in chapter 3.10. The break-even point for BOKS lies at 14 trips. From trip 15 onwards BOKS will emit less CO2 compared to a regular cardboard box with insulation liner.

For an estimated lifetime of 100 cycles this will mean that BOKS emits a total of 17 kg of CO2. Whereas using 100 individual cardboard boxes will emit a total of 54 kg CO2. This accumulates to a 68.32% savings of CO2 emissions per trip.

Various parameters are discussed to lower the emissions further. Hence, fewer trips are required to reach break-even which increases the emission savings per trip. It was found that decreasing the weight and choosing the right cleaning method were the most effective parameters.

Other parameters include increasing the return rate and the amount of recycled contents. These are discussed in chapter 3.10 and elaborated in chapter 2.9.

Materials

Insulation

For the insulation layer, both flax and hemp were selected as potential materials. Both are characterized by comparable thermodynamic properties, see chapter 3.6. Both materials can be sourced and processed in the Netherlands. Making use of locally sourced materials decreases the impact of transportation and it is a convincing element in the story of BOKS.

David Kasse, an advisor at Flax & Linnen NL, states in an interview that these materials are quite similar except for the fact that growing hemp does not require any fertilizers or pesticides (D. Kasse, personal communication, June 6, 2021). Therefore it can be sourced completely organic. Based on the previous, hemp is considered the best fitting and most sustainable insulation material for BOKS.

Case

The main function of the case material is to extend the lifetime as long as possible. It does so by adding structural strength, preventing air leaks and protecting the hemp layer from moisture. The combination of these functions requires a durable material with good resistance to cleaning detergent and water.

Polypropylene (PP) is found to be the best fitting material for the case. This material is also recommended by Caroli Buitenhuis, bioplastics expert at green serendipity (C. Buitenhuis, personal communication, April 29, 2021). The material is proven to function in the context; it is widely used for packaging purposes and it could be approved for direct food contact.

Besides being perfectly recyclable, PP is also able to withstand moisture, chemicals, and heat which makes them durable in the given context. Since PP is recyclable it is chosen to incorporate recycled content in the material. This reduces the need for virgin materials, this is elaborated in chapter 3.10.

2.6 DC4 : Goodcase

Optimize the solution to become an asset for Goodcase Packaging. The product should focus on inspiring consumers with a high quality experience. Simultaneously, the solution should be easily adaptable to other webshops while keeping the costs for usage low.

BOKS experience

The interaction with BOKS is designed to be recognizable and intuitive. Its aesthetics are minimal. From an outside perspective only the buttons are highlighted to communicate how to open it, see figure 8. Opening might feel like opening a treasury. The folding of BOKS can only be performed in one way, which resembles folding a cardboard box. The folded BOKS is easy to transport, see figure 9. These references make interacting with BOKS feel like you did it before.

A transitory business model with a reward system is found to be best fitting for this use case. The business model is derived from various circular case studies which are described in chapter 3.7. From the cost analysis in chapter 3.9 it was concluded that BOKS can be offered at a competing price of €3.19.

Investments in the first years are required in order to set up the system. The financial model, indicates that BOKS shows potential to become profitable within 3-4 years depending on the growth rate. For Goodcase Packaging it can be concluded that BOKS definitely has potential, however further analysis is required, see chapter 2.9.

Its generic design allows BOKS to be suitable for various webshops. Revenue is generated by selling BOKSES to webshops. The flow of BOKSES also generate data which provides relevant insights to continuously improve the service. Each box is tagged with an unique ID which is scanned at each stakeholder, see figure 10. This allows the system to calculate and display real-time data.

Data Gathering

This data is relevant for:

- **Goodcase packaging** as it allows them to monitor the performance of the system in real time. For example, it allows them to calculate optimal reverse logistic operations and hiccups could be anticipated which allows smooth performance at any given moment. Besides this, the data allows Goodcase packaging to keep track of the performance of the webshops and the reward program.

- **Webshops** because they are interested in knowing if their products arrive at the customers within time and they want to get higher discounts on their packaging. In order to do so, they need to be aware how many of their customers are returning the boxes. In addition, the system provides insights in the overall carbon reduction which they can use to increase their sustainable performance and brand perception.

- **Customers** because they are interested in receiving insights into their performance. They want to know how much carbon emissions they saved. This data creates a richer product experience, which hopefully results in more awareness.

Figure 8: Opening BOKS
Figure 9: Transporting BOKS
Figure 10: Unique BOKS ID

2.7 Additional Challenges

In this section additional challenges and their solutions are described based on the design fundamentals.

Design for contin-use

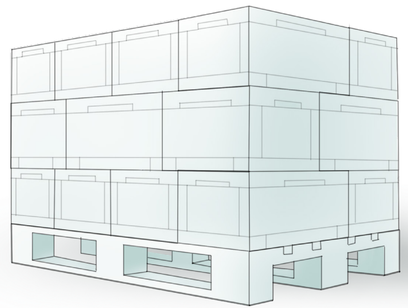
Design

Each main stakeholder in the loop has different expectations and interactions with BOKS. Wishes from each stakeholder were tried to be incorporated as much as possible during the design phase.

- **For webshops** this has resulted in a folding mechanism to store the BOKSES without taking up too much space. Expanding the box can only be done in one intuitive way, not taking more time than a cardboard box would. BOKS is perfectly stackable on a pallet, the stacking mechanism is comparable to that of beer crates, see figure 11.
- **For customers** the folding mechanism is beneficial to save space once the BOKS is no longer needed. The folding interaction is similar to folding a cardboard box which makes it intuitive.
- **For logistics** BOKS does not have organic shapes or large roundings to make it better stackable. This way it fits the context with cardboard boxes. The handles make it easy to carry the boxes. In addition, the folding mechanism allows for efficient reverse logistics.

Material choice

The material has a large impact on the lifetime of the product. Polypropylene is chosen as it is characterized as a durable material with good mechanical properties. Its strength and fracture toughness are the properties that make BOKS truly durable.



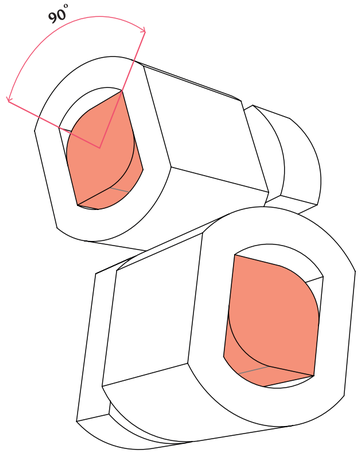


Figure 11: Pallet with BOKSES
Figure 12: Hinge with 90 degrees range of motion
Figure 13: BOKS brand
Figure 14: Parts overview

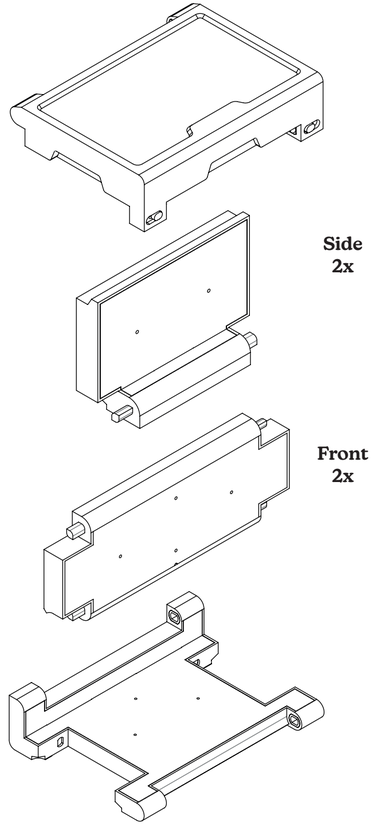
Design for flow

Incentive system

The return system is elaborated before in chapter 2.4. Creating incentive is crucial in order to make a system with reusables work. The system aims to create incentive by involving both the customer and the webshop in the process. Although the current method is concluded from the research to be the best fitting with this use case, it definitely requires additional research and validation.

The BOKS brand

BOKS will need to become a movement that makes reusing cool. Hence the name BOKS which refers to the fist bump. The logo aims to reinforce this by showing the impact of the fist bump. In addition, the logo can be expanded to create a whole line of fist bumps simulating the flow from stakeholder to stakeholder, see figure 13.



Design for repairability

Modular design

BOKS is designed with modularity in mind. Each panel is interchangeable for easy reparations. The insulation layer can be replaced if needed since the inner panels are connected to the outer panels making use of reversible connections. The axis is designed as a separate part which is connected to the panels from the inside during assembling BOKS, see figure 12.

Reduction of individual parts

Besides being modular the amount of individual parts per BOKS is reduced. The left and right side panel and front and back panel are identical. This makes repairs and assembling less complicated and so the chance of faults is reduced, see figure 14. In addition, this reduces the need for two parts. Subsequently, the amount of molds is reduced which will lower the cost price.

Design for low maintenance

Material choice

Polypropylene is a durable material that does not require extensive maintenance. In addition its excellent resistance against water and detergents makes polypropylene a well suited material for this use case.

Cleaning

The inside of BOKS is smooth, which should contribute to the decrease buildup of unwanted odours and dirt on the inside. Therefore, the inside is easy to clean.

2.8 Program of Requirements

The requirements in the list are organized based on the design challenges. A distinction is made between 'must have' and 'nice to have' requirements.

Requirements are based on one of the four sources below:

1. The parametric models
   a. Thermodynamic model
   b. Financial model
   c. LCA Tool
2. Physical testing
3. Research including papers and expert interviews gathered during the analysis phase
4. Assumptions based on experience gained during this project.

Each requirement is assessed and assigned a colour based on how well it is met.

- **Green = requirement is fully met, there is no need for further actions.**
- **Orange = requirement is partially met, a concise plan with further actions is described to solve the problem.**
- **Red = requirement is not met, further research is needed. A clear plan is needed to solve the problem.**

DC1 : Performance

Must haves

- **The products should stay below 5 degrees for at least 36 Hours (1a + 2).**
  From preliminary tests and tests with the final prototype it was found that the insulative properties of BOKS has the potential to keep products below 5 degrees for 36 hours. This is true for frozen products and requires a specific amount of coolant.
- **The solution should be able to function as intended within the timeframe in an average temperature of 27 degrees Celsius. Conform ISTA 7E (1a).**
  Data from the parametric model shows that BOKS is capable of performing as intended to conform the ISTA 7E profile. This requires additional coolants as described in chapter 3.8.
- **The products should be kept cool without using active energy sources (3).**
  BOKS makes use of passive cooling.No additional active energy input is required to keep products cooled.
- **The cooled volume should at least be 300 x 200 x 150 (4).**
  The cooled volume is 33.4 x 23.4 x 16.
- **The volume should be as large as possible for the smallest boundary surface area (3).**
  A smaller surface area will decrease the heat flow through conduction. A square would have been the optimal shape, however, this is not ideal for the contents, the folding mechanism and logistics. A much more stable rectangular shape is designed with minimal surface area.
- **The thermal conductivity needs to be as low as possible (3).**
  The thermal conductivity of hemp is 0.2 [W/mK] which is considerably low for a natural material.
- **The specific heat capacity needs to be as high as possible (3).**
  The specific heat capacity of hemp is 1200 [J/kgK] which is considerably high for a natural material.
- **The cooling compartment should be free from gaps to prevent warm air from entering the system (3).**
  The compartment is largely free from gaps, however two small gaps are still open on the sides. The folding mechanism results in many mating areas with small tolerances which is not beneficial for the thermal performance. Preventing this requires additional work which is described in chapter 2.9.
- **Dead space in the cooling compartment should be kept minimal (3).**
  Currently the dead space in the cooling compartment is not dealt with. This can be solved with a buffer material which should be reusable as well.
- **The solution must last for at least 50 cycles (4).**
  The solution is estimated to last 100 times based on the lifetime analysis of beer crates. However, this remains an estimation and requires further research and validation.

Nice to have

- **The weight of the insulation layer + coolant should be max 3 [KG] (4).**
  The weight of the insulation layer is about 400 grams. The amount of coolant depends on the type of food and the environmental conditions. For a scenario of 21 degrees Celsius 5 cooling packs are required with a combined weight of 2 kg. This will keep the overall weight under 3 kg.
- **The wall thickness should max 4 mm (4).**
  The current wall thickness is 4 mm, which is over dimensioned on purpose. The wall thickness is one of the major parameters determining the overall weight of BOKS. A plan to decrease the wall thickness is presented in chapter 2.9.
- **The solution should not degrade on the shelf (3).**
  Polypropylene is a durable material that will last for years. Hemp insulation is often used for insulation of houses, which confirms its consistent performance over a long period of time.
- **The insulation should not be affected by moisture or should be protected from moisture (3).**
  Hemp should not be in contact with water too often, otherwise its performance will decrease over time. If it comes in contact with water, it needs to dry properly before being used again as an insulator.

DC2 : Reuse

Must haves

- **The product should be modular which makes it easy to clean, repair and refurbish (3).**
  BOKS consists of modular panels which are easily interchangeable. This allows for easy repairs and cleaning.

- **The inside of the compartment should be smooth and non-porous for easy maintenance and better safety performance (4).**
  The inside is made of PP, the surface area is smooth. This is beneficial to prevent dirt buildup and eventually the development of undesired odours.

- **The cost for returning the product should be lower than €1.00 per parcel (1b).**
  The cost for returning is €1.81 in bulk shipment. This is estimated to be the most efficient for reverse logistics.

- **A fitting reward scheme should create incentive to return the package (3).**
  The designed reward scheme aims to actively involve both the webshop and the customer in the return process. Incentives are created based on monetary gains which is one of the strongest incentives. However, this reward scheme definitely needs further validation as described in chapter 2.9.

- **The product should be compact for efficient transport (3).**
  BOKS is foldable which results in a 40% volume reduction. This allows for efficient transport.

- **The solution should be easily collapsible for returning (3).**
  BOKS is foldable.

Nice to have

- **Reusing needs to be convenient, educational and purposeful (3).**
  Through data gathering of the flow of BOKS stakeholders can be actively involved and educated about their performance. This could contribute to creating more awareness about the circular economy and the shift towards conscious consumption.

- **Returning the solution should be fitting in current infrastructure (3).**
  By making use of supermarkets and drop-off points BOKS taps into current behaviour of consumers. Therefore it fits well in the current logistic infrastructure and it does not require additional investments in creating new drop off points.

- **The solution should be easily recyclable, compostable or soluble (3).**
  Hemp is completely compostable. PP is perfectly recyclable.

DC3 : Sustainability

Must haves

- **The solution must consist of mainly renewable materials (3).**
  Hemp is a renewable completely organic material which can be harvested and regrown. Polypropylene is not renewable, however it is perfectly recyclable.

- **The solution should harm the environment as little as possible (1c).**
  Compared to single use cardboard boxes the overall CO2 emissions are reduced by 68% per trip. The break even point for CO2 emissions is reached after 14 cycles. Other environmental impact factors need to be assessed as well in order to make a well ground argument.

- **The solution should be easily recyclable, compostable or soluble (3).**
  Hemp is completely compostable. PP is perfectly recyclable.

- **The product should be producible in the EU, preferably making use of (dutch) waste streams (3) .**
  Hemp is sourced in the Netherlands, in theory PP can be produced in the EU as well.

Nice to have

- **The flow of the product needs to be monitored to generate data to further improve the system(3).**
  The flow of BOKS generates data as it is scanned at every touchpoint. This data is beneficial to continuously improve the quality of the system.

- **The product should generate awareness about the environmental impact of our packaging (3).**
  Data insights from the flow could generate awareness about packaging and our way of consumption. This remains, however hypothetical.

- **Data generation should be transparent for consumers to generate extra awareness (3).**
  Yes, the data gathering part is not detailed enough to make a proper assessment.

DC4 : Goodcase

Must haves

- **All materials in direct contact with food should be FDA approved.**
  PP can be approved by the FDA for direct food contact. However, given the use case direct food contact will not be the case. So this requirement is less relevant. For different markets with direct food contact, PP could still be used.

- **The cost per usage should be comparable to market alternatives (avg. estimation €3.00) (3 + 1b).**
  The cost per usage is €3.19 for a set of one BOKS and three ice packs. With the reward system this could eventually become €2.97.

- **The cost price should max be €15.00 (1b).**
  The cost price is estimated at €15. This assumption is based on experience.

- **The outer dimensions of the box should fit with Europallet and Box pallet standards (120 x 80 cm) (3).**
  The outer dimensions are 40 x 30 x 25 which fits perfectly on a pallet. The extrusions at the bottom and indents at the top allow for easy stacking.

2.9 Recommendations

For further development of BOKS, product and system related concerns and improvements are discussed in this section. Each concern is derived from the analysis described in chapter 3. Their impact on the overall performance is assessed making use of the three parametric models.

Improvements for contin-use

The contin-use approach is updated to match the improvements described below. Initially it was assumed it was beneficial to extend the flow time like for example many initiatives in the clothing market. However, for this specific use case it works the other way around. Decreasing the flow time is beneficial from both a financial and an environmental perspective. Additional measures are described to add more value to the design and find the optimal reward value.

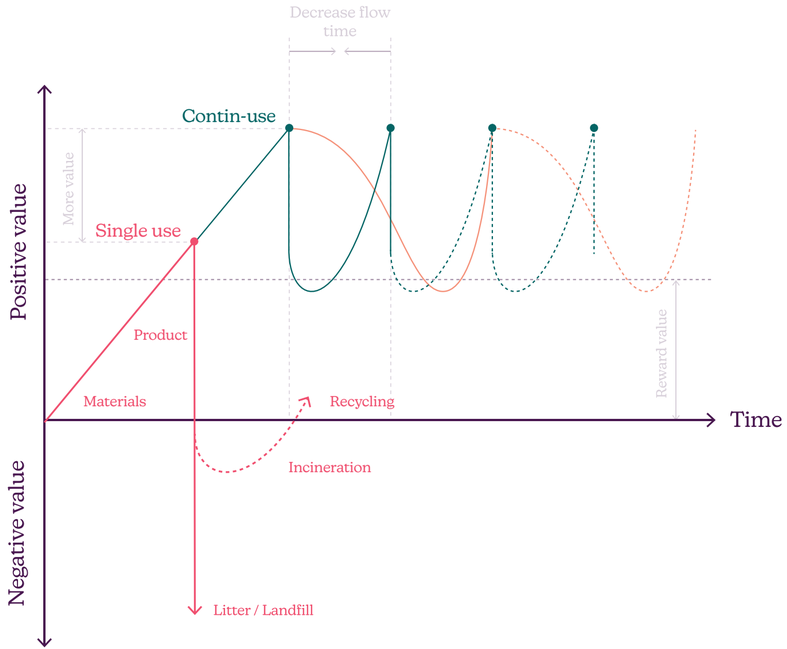


Figure 15: Contin-use model improved

Decrease flow time

Flow time

The flowtime is the average total time it takes to make one loop. This parameter affects both the financial and the LCA model and should be kept as low as possible.

A shorter flowtime means less required BOKSES. This requires less investment in the production of new BOKSES which is beneficial to keep the costs low, see table 2. The current system is designed for a flow time of 20 days. Alterations in the flowtime mainly affect the outcome of the financial model, but also less production results in fewer CO2 emissions. Decreasing the flowtime is thus beneficial from a financial and environmental standpoint.
Both the webshop and the customer are identified as potential stakeholders that have the biggest impact on flowtime. Promoting lean buying in combination with a fast service could prevent excessive stacking at the webshop. Making dropping off BOKS more convenient in combination with appropriate rewards and active nudging could help decrease the flowtime at the consumer.

Flowtime [days]	BOKSES req.	CO2 emissions during production [kg]
10	171	225.4
15	257	338.8
20 (current)	342	450.9
30	514	677.6

Table 2: Impact of flow time modifications

More value

Minimize weight

The weight is mainly affected by the wall thickness of the case layer. Decreasing the wall thickness affects the LCA and the thermodynamic model.

The current wall thickness of 4 mm is overdimensioned on purpose. However, this results in an unacceptable weight of 2.9 kg, see table 3. Decreasing the wall thickness decreases the weight which results in less CO2 emissions per trip. It is interesting to see that the cooling time is not affected much by these alterations, a 63.5% decrease in wall thickness results in a 3.3% decrease in cooling time. This is positive as it allows BOKS to be designed as lean as possible. This will also have an impact on the cost price, however the cost price remains an estimation so no validated effects can be described.
A concern for decreasing the wall thickness is the structural performance. Adding ribs could be required to increase the stiffness and overall strength. This needs to be tested with actual materials in a simulated environment.

Wall thickness [mm]	Weight [kg]	Break even CO2 [trips]	CO2 savings per trip [%]	Cooling time [Hr]
4 (current)	2.98	14.0	68.32	36.5
3	2.20	10.0	75.64	63.1
2	1.45	6.3	82.97	35.6
1.5	1.08	4.7	86.63	35.3

Table 3: Impact of wall thickness modifications. Cooling time is calculated for scenario of 3 kg + 5 ice packs at 21 C.

More value

Cleaning method

The method of cleaning plays a major role in the environmental impact. The cleaning method affects the LCA model. In addition it requires product changes to make it more waterproof so the hemp layer will last longer.

Washing is required to prevent dirt build up and undesired odours. From the analysis in chapter 3.9 it was found that industrial grade washing installations are considerably more efficient and less impactful compared to hand washing methods, see table 4. However, industrial grade washing installations do require substantial investments and scale to be operating at an efficient rate. Nonetheless, the environmental benefits of industrial grade washing are considered significant.

Cleaning method	CO2 emissions [kg]	Break even CO2 [trips]	CO2 savings [%]
Industrial (NaOH)	0.01	14.0	68.32
Consumer grade washing	0.03	15.8	59.42
Handwashing	0.10	24.8	33.76

Table 4: Impact of the cleaning method

Reward value

Reward program

This might be the biggest improvement point to focus on. Finding out which rewards works optimal. Reward affects the financial model, but could eventually also affect the other models if drastic product changes are found to be required.

Rewards differ per customer segment. Finding the right reward value is assumed to be critical to increase the return rate and to decrease the flow time. Applying a market principle would suggest the optimal value is found by the webshops over time. Determining the optimal discount for the webshops requires further investigation with actual webshops and their customers.

Improvements of performance

Leaks

BOKS does not completely close off the inside from the outside environment. Therefore the thermodynamic performance is inefficient. In addition condense could leak through the cracks at the mating areas of the panels.

BOKS is not completely free from gaps. Due to the folding mechanism there are two gaps on the sides which have direct contact to the environment. This affects the thermodynamic performance. This inefficiency is not included in the thermodynamic model, therefore a discrepancy is expected. Improvements on the folding mechanism need to be considered to remove the gaps.

In addition, condense created during the trip could leak from the cracks at the mating areas of the panels. A rubber packing at the mating areas could close off these gaps and simultaneously prevent air from leaking through the cracks.

Case material

The current case material does require virgin materials. To further decrease the environmental impact and create more awareness completely 100% recycles should be explored.

An example of such a material is the recycled HDPE from the ocean cleanup. That material is currently used to fabricate sunglasses. Performance wise the material shows comparable properties to the PP currently used. The main benefit is that the material creates more awareness by telling its story. This story could be a great asset for the educational intentions of BOKS.

Buffer materials

The inside volume of BOKS is not adaptable to the volume of the products. As a result part of BOKS will be dead space which makes the thermal performance inefficient.

Buffer materials are required to keep products in their place and protect them during transport. This could be prevented by adding a partition wall which can move from left to right inside BOKS. This prevents shifting from products and allows for efficient cooling without creating additional waste.

Improvements business case

Investments

Considerable investments are required to start production and operations.

The required investments for operations need to be assessed in order to come up with a strategy for funding. For example investments for warehousing, logistics infrastructure, production of BOKSES, cleaning installations, online platform and service operations. With these costs, the viability of the business case can be assessed.

Other markets

Other markets need to be assessed.

The mealbox market might be more interesting to focus on initially. These markets have a high return rate because mealboxes like hello fresh and marley spoon are subscription based. This takes away the need for customers to return their BOKS at their local dropoff point. BOKS can just be picked up with the next delivery, which provides a predictable and shorter flowtime. In addition, marley spoon and hello fresh are companies with substantial scale to allow for efficient operations.

Improvements user interaction

Opening and closing actions

Enhance the user experience by making interactions more intuitive.

The closing mechanism needs to remain unlocked for a short amount of time once it is slid outwards. This allows the user to open BOKS with the handle on the front. The closing pins need to be chamfered properly in order to allow BOKS to close automatically once the lid is in horizontal state, see chapter 3.11. The same counts for closing BOKS in the folded state. It is barely visible for the user if it is locked and there is no confirmation (click) that it is locked.

Folding instructions

The current design does not communicate how to fold BOKS.

In addition, signifiers are required to communicate how to fold BOKS. Although all parts can rotate 90 degrees in only one direction, it does not communicate to the user what that direction is. Clear instructions will speed up the folding process.

A reflection on the project can be found at page 98

Research

Description of all analysis performed during this project

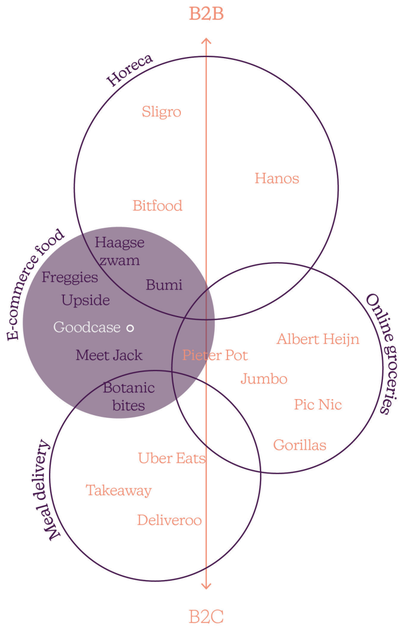


Figure 16: Market focus

3.1 Scope & Market Analysis

The main goal of this analysis is to narrow down the project scope from the project brief described in appendix I and to reach a conclusion based on the assessment of various use scenarios. From this analysis it has been decided that a generic solution is favorable over a specific one. In addition it was found that passive cooling has a lower environmental impact compared to active cooling. Lastly, a reusable solution is favored over a single use solution.

Generic or specific

Besides customers of Goodcase, the identified target group also includes Goodcase Packaging, food webshops and their customers. The last mentioned is crucial in order to decrease the environmental impact of current cooling solutions on a larger scale as described in chapter 3.4. A generic solution, capable of fitting multiple use cases for various companies, could in theory create more positive impact. This is strengthened by various suppliers delivering directly to customers (DTC) mentioning that current solutions hold them back in their operations. They indicated to be interested in a better performing solution, see appendix B. In addition, selling cooling with low environmental impact has the potential to become an additional revenue source for Goodcase Packaging as described in chapter 3.7. Producing in larger quantities will decrease the price, see chapter 3.9. Therefore, it is decided to favor a generic solution over a specific one.

Passive or active cooling

Cooling is defined as the removal of heat, usually resulting in a lower temperature and/or phase change (ASHRAE Terminology, z.d.). Cooling techniques are either passive or active. Active cooling requires energy input in the system whereas passive cooling does not require any energy input (Geetha & Velraj, 2012, p. 928). In transport, active cooling is predominantly used in large volume logistics such as business to business deliveries (B2B). However, our target group is mainly focussed on delivering to consumers (B2C). They make use of external suppliers and prefer to ship with regular transport to keep the cost low. Therefore, passive cooling is indicated as the preferred cooling technique by our target group, see appendix B. As mentioned in the interview by Karlijn Pennarts, product owner PostNL Food, passive cooling is concluded to be more sustainable compared to active cooling, less energy is consumed whilst transporting

the products, see appendix G. In addition, with mixed boxes, containing cooled and uncooled products, it is of course most efficient to only cool the required products.

Passive cooling requires shorter delivery times. Current trends in logistics show that same day delivery is becoming a standard as described in chapter 3.2. Research from McKinsey indicates that same day and instant delivery will have a combined market share of around 20-25% by 2025 (McKinsey & Company, 2016). Currently, various carriers are already specialized in offering same day and next day delivery, of which Trunkrs, vanavondbezorgd and Redjepakketje are most preferred by our suppliers, see appendix B. In an interview, Rein Hofhuis sales manager at Red je Pakketje, stated that they are capable of providing two delivery moments within 33 hours with a success rate of 98% on the first delivery, see appendix G. These carriers are taken into account for the logistic journey map presented in chapter 3.3.

The quest for speed also increases the price, within the range of €6.50 to €9.50, see appendix H. A research performed by McKinsey & Company in 2016 concluded that around 23% of customers indicate to be willing to pay extra for same day delivery. Price remains however the dominating factor, as 50% of the customers prefer the cheaper over the faster option, if they had the choice. This phenomenon is confirmed by Rein Hofhuis, see appendix G. For perishable goods there is not much choice, hence the inevitably higher delivery rates. The increase in growth over the past years of aforementioned couriers indicate the willingness of consumers to adopt such rates.

Carrier	PostNL Food	Red je Pakketje	Trunkrs	Vanavond bezorgd
Cooling	Passive	Passive	Passive	**Passive**
Price [trip]	€12.00	€8.30	€7.70	**€8.95**
Time	Same day	Next day	Same day	**Same day**
MOQ	Negotiate	1	100/week	**1**

Table 5: Carrier comparison.
The table below shows prices for sending a package of €35, prices are non-negotiated from their websites and excluding VAT. Price is estimated to drop for higher quantities.

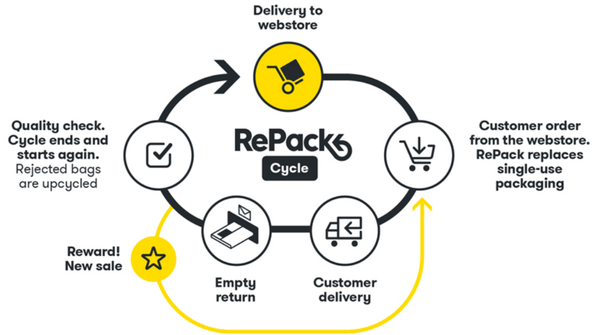
Reuse or single use

In this section different scenarios are assessed to determine whether a reusable solution is desirable. Making a solution reusable decreases its environmental impact per usage and is therefore favorable over a single use solution (Boz, 2021). Less material is used and the product life time is extended to its full potential. It is analysed what a reusable solution and its logistic system would look like. Two scenarios are described, one where the cooling box is being used by the courier service (internal) and one where the recipient receives the cooling box and subsequently returns it (external).

The proposed advantages for internal usage are reduction of additional costs and risk for recollecting as the product stays in the loop. For this specific purpose reusing also has disadvantages as Karlijn Pennarts from PostNL Food describes: 'Compared to the parcel market, food delivery is fundamentally different. PostNL Food employees take the cooled products out of a reusable cooling box at the customers' door. As a result operations are the major expense in the delivery rate', see table 5.

For the external scenario, the user receives a reusable cooling box delivered with a parcel courier. Which is subsequently returned to Goodcase or an external organisation handling recollecting. Suppliers and customers indicate that such a solution would be ideal, as it would be more sustainable as described in appendix B.

Figure 17: RePack reward scheme explained



However, the challenge is to make reverse logistics feasible both logistically and financially. 9% of all shipments in the Netherlands are returned, with this rate we are the frontrunners in Europe (Emerce, 2018). Currently, fashion webshops pay an average of €12.50 per return shipment. These costs are usually paid by the webshop, as it increases chances of returning customers. This shows that reverse logistics is expensive.

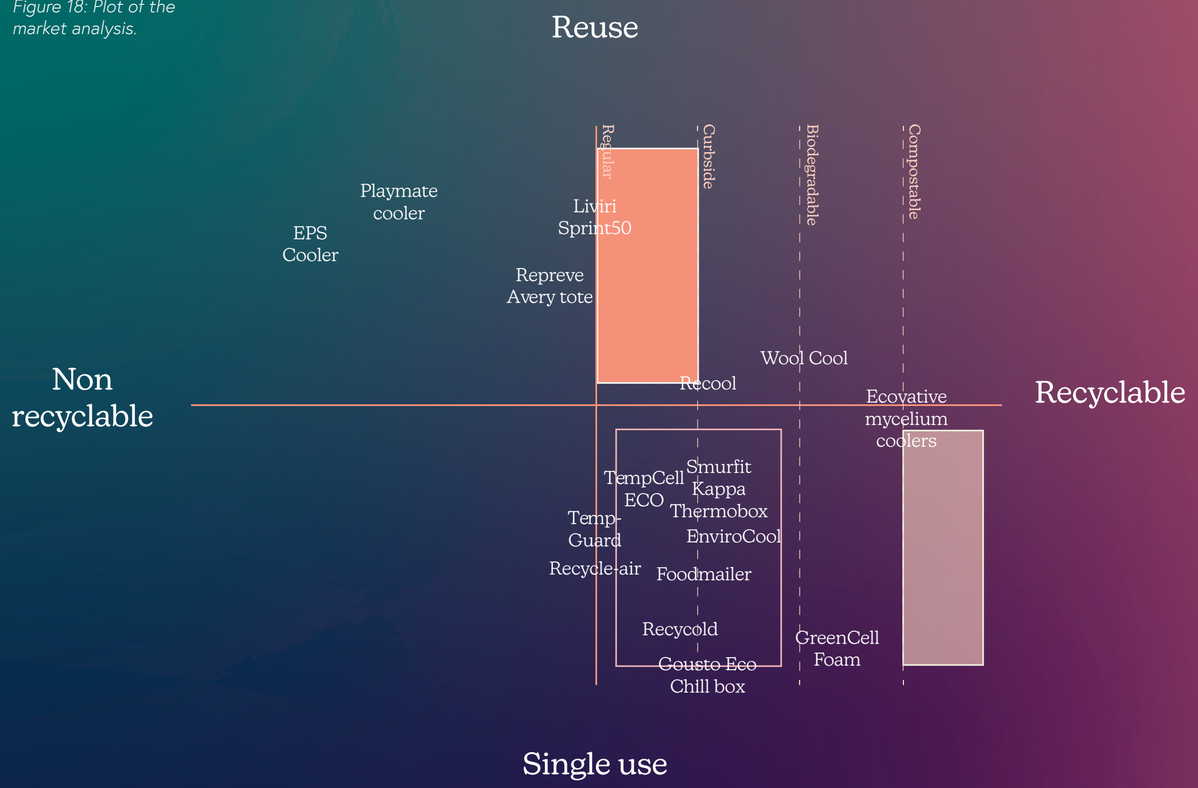
For internal recollecting, Herwin Wichers states in an interview (see appendix I) that besides transport additional costs will be made for collecting, cleaning and processing reusable boxes if they are returned at all. RePack reports a return rate of 75%, which is considered high. Marijn Prijs, CEO of returnless, adds that reusing works best with a subscription model where the customer pays a deposit for the box beforehand. This incentivises the user to resend and therefore decreases risk of lost goods, see appendix G. Research by the Ellen McArthur Foundation in 2019, addresses this incentive challenge by advocating for a reward scheme like RePack does in figure 17. Such a system takes away the barrier of paying upfront and leads to higher brand loyalty.

Instead of internal collecting it could be feasible to explore external recollecting. RePack is a perfect example for this. They create reusable ecommerce packaging that can be returned with a letter post without extra costs for the customer (RePack, z.d.). Recollecting, cleaning and processing is performed by them. Their reward scheme connects webshops in a marketplace that provides discounts for their customers. This is all taken care of at a premium price compared to cardboard boxes. Therefore RePack is mainly used by conscious premium brands where margins tend to be higher.

In a third scenario the customer receives a single use solution, with a low environmental impact. For customer convenience, such a solution should fit within current recycling streams meaning it should be curbside recyclable or easily compostable. The main downside of this is the fact that materials need to be reprocessed continuously while their properties will deteriorate. This reprocessing was found to have higher impact compared to reusing as described in chapter 3.10.

It is concluded to focus on a reusable solution with external recollecting. This recollecting will be investigated which results in the need for a new company: Goodcase Packaging.

Figure 18: Plot of the market analysis.



Market analysis

Figure 18 describes the analysis of available products on the market, see appendix J for the full list. A division is made between Reusable and single use products. They are mapped on a scale of recyclability based on the waste hierarchy discussed in chapter 3.5. The figure shows that the category of single use recyclable cooling solutions is quite saturated. This area is mainly filled with cardboard insulation boxes. Other areas show little alternatives.

Therefore two main focus areas were distilled from this analysis:

- **Single use compostable**
  Creating a single use solution from resources that can be returned to the soil could be a way of minimizing environmental impact.

- **Reusable and recyclable.**
  Biodegradable and compostable materials usually degrade fast by environmental influences. Making products last longer decreases its impact, therefore it is chosen to favor recyclable over biodegradable and compostable.

In line with the principles of the circular economy described in chapter 3.5 the reusable solution is favored over the single use solution. The project will be focussed on creating a generic passive cooling solution that is also reusable.

Key Insights

Scope and Market analysis

- A generic reusable passive cooling system is considered to be best fitting the requirements.
- Current trends in logistics and customer acceptance make passive cooling a viable option for transporting perishable goods.
- Pursuing a generic solution allows Goodcase to decrease the environmental impact of transportation of perishable goods on a larger scale. The solution has the potential to become an asset that's sold to other businesses.
- Goodcase Packaging needs to be created for recollecting the reusable solution.
- Reusing fits best with the Goodcase DNA.
  - Goodcase aims to be the frontrunner in the transition to a more sustainable world. That includes bringing new developments to consumers.
  - A reusable solution allows for an optimized user experience and has the potential to generate the consumer awareness Goodcase is after.
  - A reusable and biodegradable or compostable solution has the most potential to be disruptive and innovative in the current market.
  - Collaborating with an external party for the fulfillment of returns allows Goodcase to offer our customers sustainable packaging at a competing price

3.2 Logistic Forecast

In this analysis the current courier, express and parcel service system (CEP) in the Netherlands will be analysed and used as a basis to project future developments in order to describe the logistic landscape of 2030. This analysis focuses on the delivery of fresh foods in urban areas, prepared meals are not included. Results show a switch to electric vehicles which leads to rethinking logistics in order to increase efficiency.

Current logistic system

The Topsector Logistiek predicts a yearly CEP market growth of 10%. This represents a growth factor of 2,59 for the year 2030. The COVID-19 pandemic accelerated this growth of the CEP market even further, especially for food delivery. Since the beginning of 2020 online orders for groceries have increased 25%. This segment accounts for 4% of the total supermarket revenue (Supermarkt en Ruimte, 2020).

PostNL is the biggest courier followed by DHL with a market share of 60-65% and 25-30% respectively (ACM, 2019). The conventional delivery van is still the preferred mode of transport because of their large loading capacity and range. However, innovative parties like Fietskoerier and Goupil (Picnic) force the bigger players to explore light electric vehicles (LEV) for delivery too. Especially in dense urban areas, with less space and high stop density, LEV's could be favorable. However, research by Ploos van Amstel et al. states that LEV's could replace only 10-15% of regular logistics, as they are best used in market segments with low weight and volume transportation.Therefore they describe LEV's most promising opportunities lie in the food sector.

Consumer perception

Delivery

In recent research by PostNL it was found that 81% of consumers indicate that they are willing to choose for the lowest emission option for their delivery, however only 6% indicate that they are willing to pay extra for this. On the other hand, 58% state that they do not mind waiting an extra day for lower emission delivery (PostNL, 2020). The question rises if this level of flexibility is applicable for perishable foods.
Perishable foods need to be delivered within a short timeframe. Current CEP trends show that same day delivery is becoming a standard. Research from McKinsey and Company indicates that same day and instant delivery will have a combined market share of around 20-25% by 2025 (McKinsey & Company, 2016). The infrastructure for same day delivery is improving, which could generate opportunities for the transport of perishable goods. Currently, various carriers are already specialized in offering same day and next day delivery, of which Trunkrs and Red Je Pakketje are most preferred by our suppliers (see appendix B).

66% of consumers state that the main reason for unsuccessful deliveries is not being able to modify the date and time of delivery. Consumers prefer to set the time and date over faster delivery (PostNL, 2020). The level of flexibility with food delivery is smaller and the impact of unsuccessful delivery is larger compared to normal parcels. Therefore it requires efficient communication. Same day deliveries usually happen in the evening between 17.00 and 22.00, for the highest success rate. In addition, Mieke Steenbrink (Vanavondbezorgd) states in an interview that real time communication is used to notify the consumer in time about the exact delivery moment, see appendix G.

> "Same day and instant delivery will have a combined market share of around 20-25% by 2025."
>
> McKinsey & Company, 2016

Packaging

When it comes to packaging, paper is the preferred option over plastic alternatives. 54% of UK customers indicate to favor paper because they believe it is better recyclable (Two Sides, 2021). 45% of the consumers indicate that too much packaging material is used and boxes are too big (PostNL, 2020). This indicates that the insulation should be as lean as possible which is confirmed by Herwin Wichers in an interview, see appendix I. He states that styrofoam (EPS) is the best insulator available and that any other material will thus be thicker to reach similar insulation performance. Compared to high carbon footprint solutions such as EPS, a low carbon footprint solution could still evoke negative associations because more material is used. This implies that consumer perception about sustainability might not reflect actual sustainability performance. He continues by emphasizing that storytelling and third party certification could contribute to decreasing this discrepancy.

Figure 19: Cardboard boxes (Pixabay Cardboard boxes, 2020).

Consumers favor paper packaging over other single use alternatives such as plastics:

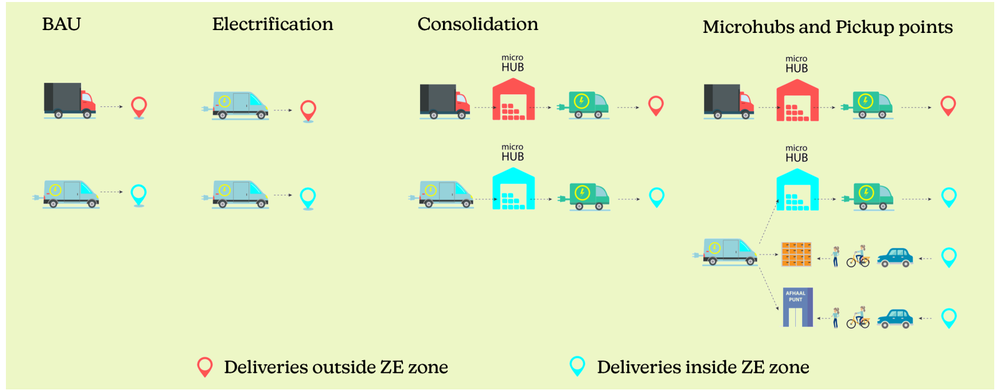
When ordering products online

54%

of UK customers prefer products to be delivered in paper packaging.

Two Sides and Toluna, 2021

Figure 20: Logistic scenarios, Topsector Logistiek, 2020, modified.



Logistic forecast for the Netherlands

The growth causes an increase in emissions, therefore a shift towards electric vehicles is inevitable. However, it is expected that partial electrification of the fleet and zero emission (ZE) zones do not compensate for this growth (Topsector Logistiek, 2020). Near future developments in the Netherlands are accelerated by the 'Green Deal Zero Emission Stadslogistiek' (GDZES), a law describing the city centre supply in the 30-40 biggest cities needs to be zero emission (ZE) by 2025. With this deal, the Netherlands is anticipating European legislation that states that by 2050 only emission-free vehicles may enter the city (Green Deal Zero Emission Stadslogistiek, z.d.).

The offering of EV's increases and bigger carriers are developing their own vehicles. As a result it becomes financially interesting to switch to ZE deliveries. Additionally, the assortment of LEV's is bigger, for example Goupil and the streetscooter (DHL) and other electric cargo bikes.

Besides the vehicles the logistic system needs to be optimized to account for the expected growth and the increasingly denser urban areas. The research from Topsector Logistiek proposes multiple scenarios based on current trends, see figure 20.

1. **Business as usual (BAU)**
   Delivery with EV's within ZE zones in city centres. Deliveries outside ZE zones happen with conventional transport.
2. **Electrification**
   Similar to BAU, except only EV's are used, including deliveries outside ZE zones.
3. **Consolidation**
   This scenario makes use of a microhub inside the ZE zone, from this hub small EV's deliver the parcel to the recipient.
4. **Microhubs and Pickup points**
   This scenario makes use of various hubs and pickup points. Besides microhubs described in the previous scenario, pickup points and autonomous lockers are used where the recipient could pick up their parcel.

These scenarios were subsequently analysed based on their efficiency and emissions compared to BAU. For electrification, the difference in driven kilometres is small and the emission is zero. Both consolidation and microhubs show a drastic decrease in driven kilometers (92% and 81% respectively). Emissions decrease for consolidation and microhubs, 50% and 64% respectively, since the use of conventional vehicles is limited.
PostNL indicates in their whitepaper that 38% prefer to use a car to pick up their parcel from a drop-off point which results in an unwanted increase in emissions. This stresses the need for a dense network of pickup points and lockers within walking or biking distance in case of the microhub scenario.

Developments in the rest of the world

McKinsey and Company predicts a technology driven approach with autonomous vehicles driving across the city and drones delivering parcels to your doorstep. These technology driven developments open ways for disruptive new companies to enter the market. Autonomous driving in logistics is also mentioned by Kassai et al. (2020, 17 p.) as a promising technology. They add that autonomous vehicles will be smaller and have a lower capacity compared to regular trucks. Therefore, it is proposed this would work best in a system with micro-distribution centres or microhubs as described in the scenario above (Ducret, 2014, p. 20). Numerous difficulties still need to be solved before this technology could be implemented and it raises questions if we actually will see this technology in action before 2030.

Key Insights

Logistic forecast

- The CEP market will continue to grow in the upcoming years resulting in an increase in emissions and traffic within urban areas.
- Changes in the logistic system in the Netherlands in the upcoming years will be driven by regulations and technology.
- Partial electrification alone will not decrease emission rates enough to account for the market growth. It can therefore be expected that additional changes will be found in the optimization of the system.
  - Making use of micro distribution within ZE zones increases efficiency whilst decreasing emissions.
  - Technological advancements like autonomous vehicles could fit in such a system. However it is expected such technologies will not be implemented on the streets before 2030.

Goodcase Packaging

- Sustainable transport will become the new normal driven by regulations.
- Same day and next day delivery will be facilitated by efficiency developments in the CEP system.
- Consumer perception about packaging sustainability does not always match actual sustainability characteristics.
  - Lean packaging is essential for positive consumer perception.
  - Storytelling and third party certification are good tools for consumer engagement and education.
- There is a little consumer incentive to pay extra for sustainable delivery.

3.3 Logistic Journeymap

In this section the logistic journey of BOKS is analysed based on current logistics parties. Findings from this analysis are implemented in the thermodynamic model, the cost analysis and the fast track LCA, in chapter 3.8, 3.9 and 3.10 respectively. From this analysis it was found that the cooling time needs to be 36 hours and bulk shipment is critical to make reverse logistics financially feasible.

As described in the system, see chapter 2.4, there are two logistic streams that are important to consider.

1. **The journey from the webshop to the customer.**
2. **The journey from the customer to Goodcase packaging.**

From Webshop to customer

Various carriers were considered for this analysis, see figure 21. All information has been retrieved from either their websites, interviews and quotations, see appendix G.

From this analysis three parties have been considered with a comparable journey map. The main difference lies in the price and the minimum order quantities (MOQ). Considering the small size of Goodcase, Vanavond bezorgd is chosen as the best fitting logistics party for our case. The following journey has been generated after various interviews with this party, see appendix G:

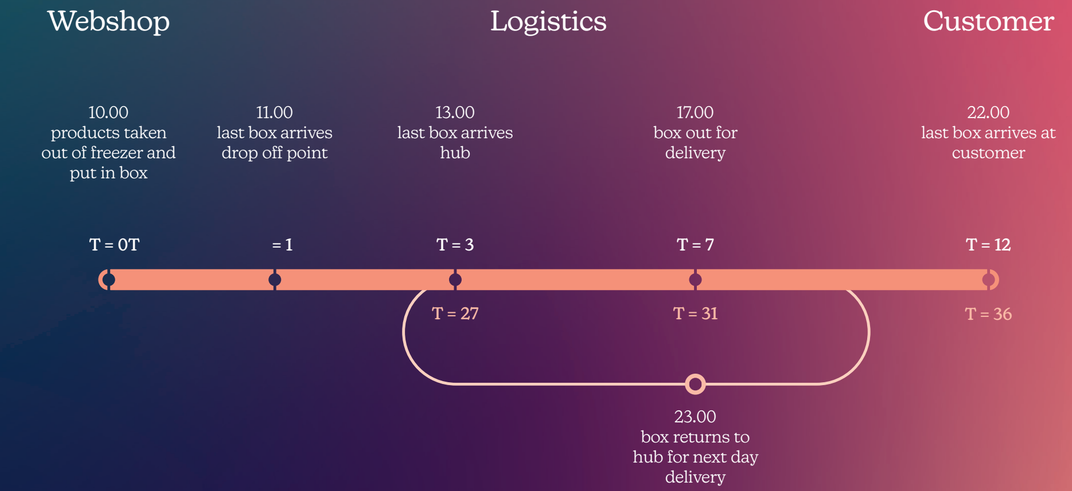
Name	Type	Column	Price	MOQ / Week	Food	Sustainable	Delivery range
Vanavondbezorgd	Delivery	Same day, Next day	€7.23	1	☑		Netherlands
Red je pakketje	Delivery	Same day, Next day	€8.95	1	☑	CO2 Neutral	Netherlands
Trunkrs	Delivery	Same day, Next day	€7.70	100	☑		Netherlands
PostNL FOOD	Delivery, Returns	Same day, Next day	€12.00		☑		Netherlands
Fietskoeriers	Delivery	Next day		10	☐	Zero Emission	Netherlands
DHL	Delivery, Returns	Next day			☐	CO2 Neutral	Netherlands
Budbee	Delivery, Returns	Same day, Next day			☐	CO2 Neutral	Netherlands
Hubbel	Delivery, Returns	Same day, Next day			☑	Zero Emission	The Haque Area
DPD FRESH	Delivery, Returns	Next day			☑		Belgium

Figure 21: List of carriers.

The map in figure 22 describes the flow from the webshop to a local drop off point. From this point it subsequently will be transferred to one of the five hubs in the Netherlands. From there on it will be sorted and out for delivery. In case the customer is not present to accept their package, the package will return to the local hub. A second delivery is attempted the next day. With this second delivery moment the vanavond bezorgd claims to have an almost 100% success rate (98% success rate on first delivery).

Perishable packages are labeled in the system of the logistic party after a fee is paid. The logistic party is not able to cool the packages in the hub. So, for the highest success rate a 36 hours cooling time is required. This also takes away stress from the webshop, as they can send their package without concern.

Figure 22: Journey map from webshop to customer



From customer to Goodcase Packaging

Boxes are collected at local supermarkets or drop off points. From there, they are picked up by a logistic service provider where they are subsequently shipped back to Goodcase Packaging.

For this journey there is less time pressure. However, the customer needs to be urged to bring back BOKS in order to keep the flowtim low, as assessed in chapter 3.9. The system also needs to monitor what the optimal bulk-pickup will be in order to have enough boxes in the loop. Therefore it is necessary that the system knows at all times what the status of each box is. From the cost analysis in chapter 3.9 it was concluded that optimal bulk shipment would require between 50 and 75 boxes.

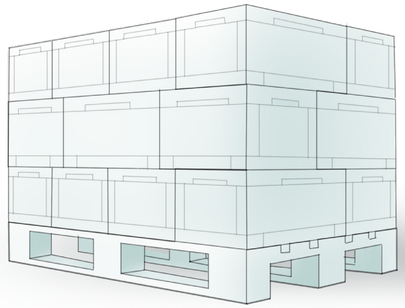


Figure 23: Bulk Shipments

Key Insights

Logistic Journey Map

- The products need to stay cooled for at least 36 hours for the highest guarantee of arriving cooled.
- Bulk reverse logistics is required in order to keep the costs low.
- Each box should have an individual ID so it can be monitored.
- Optimal bulk shipment would require between 50 and 75 boxes.

3.4 Stakeholder analysis

The system describes the flow of the reusable packaging from one stakeholder to the other. Each of the stakeholders is analysed, in order to make sure that the box flows as intended. This resulted in a system that incentivises all stakeholders to pass the packaging on to the next stakeholder.

Figure 24: Customer delivery
Figure 25: Webshop packing process

Customer

This is the most crucial stakeholder, since they initiate the recollection process. This process requires a behavioural change, which could be hard to actualize. The conscious customers of Goodcase prefer to receive their products without excessive single use packaging and some of them even indicate that they are willing to return it already, see appendix K . However, not all customers do fit in this segment, which could imply that for some customers the action of returning the box is too much of a struggle. This confirms the urge for a carefully designed external nudge that causes the behavioural change to return the packaging (Ellen MacArthur Foundation, 2020).
Designing this nudge requires a mass customization approach. Consumer preferences differ drastically per customer segment depending on the market and product. Therefore, the nudge will need to be determined by the organization that knows their customer best: The Webshops.

Webshop

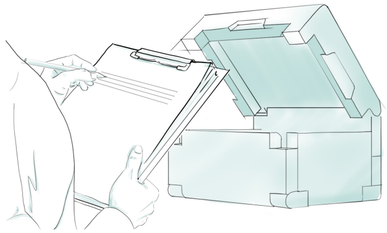
This stakeholder wants to offer their customer a sustainable waste free experience to improve their brand proposition and build brand loyalty. Goodcase is an example of such a webshop. The type of webshop and their incentive can differ based on the market and customer segment. Initial focus lies on food suppliers, from interviews it was found that they are willing to pay a little more for packaging, see appendix B. However, price remains the determining factor, especially in the food market where margins are thin as Shen Liu from Farmhouse International states in an interview (see appendix I). Cost of operations are high due to high logistics costs, as concluded from the cost analysis in chapter 3.9.

Logistics

This stakeholder transfers the reusable from one stakeholder to the other. With each transfer they generate revenue. They are incentivised to transfer as many reusables as efficiently as possible. This stakeholder is eager to implement sustainable improvements, such as Light Electric Vehicles and cargo bikes, as concluded from the logistic forecast analysis in chapter 3.2. In order to keep the operational cost for reverse logistics low, bulk transport is the preferred option. This requires a physical collection place for customers to drop off their reusable.

Supermarkets and drop-off points

his is a passive stakeholder as their main activity is accepting the reusable and allowing it to be recollected for reverse logistics. For them offering this service is mainly interesting for the fact that more people are drawn to their stores. The collaboration between Amazon and Kohl's, a warehouse in the USA, is a great example of in store returns resulting in an increase in revenue for both parties (Stidham, 2021). For customers this is a low threshold option to return their reusables.



Goodcase Packaging

This stakeholder inserts the reusable into the loop and takes care of service and maintenance operations. They own the reusable. It is their mission to provide a circular alternative to single use packaging. They are incentivised to keep the product flowing as they earn money by selling their reusables, as described in chapter 3.7. More revenue is generated as more reusables are flowing in the loop.

Figure 26: Reverse logistics
Figure 27: Goodcase packaging
Quality control

Key Insights

Stakeholder analysis

- A behaviour change is needed from the customer, therefore they are the crucial stakeholder in the system.
- A reward system is required to let the product flow from the customer back to Goodcase Packaging.
- Reverse logistics needs to happen in bulk in order to make the system financially viable.
- Price remains the determining factor for webshops when choosing packaging.

3.5 Circular Economy

In this section the circular economy is explored. Relevant principles for the use case form the basis of the design fundamentals described in chapter 2.2.

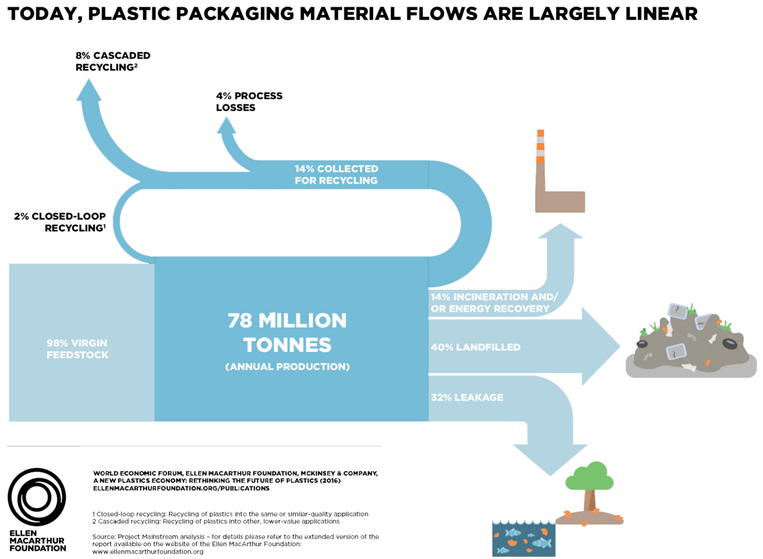
From linear to circular

Current products are mostly designed with only the production and usage phase in mind. They are designed within the linear economy. This system describes resources being captured, transformed into products and subsequently discarded as waste. Or in short: the take-make-waste system. Given the fact that resources are finite, this paradigm is unsustainable as it depletes the resources and creates an enormous amount of waste.

The main problem with creating waste is that most materials are mined, instead of harvested. The materials are man-made or man-composed with the help of machinery and production consumes a considerable amount of heat. As a result, decomposing the materials also requires effort and energy

(Haffmans & Gelder, 2020).

Figure 28: Linear economy



Shifting towards a resource-focused paradigm where materials retain their value becomes critical to sustainably deal with the resources our planet has to offer (Park & Chertow, 2014, p. 46). The circular approach as advocated by the Ellen MacArthur foundation describes 'an economy based on the principles of designing out waste and pollution, keeping product and materials in use, and regenerating natural systems' (Ellen MacArthur Foundation, z.d.).

The new plastic economy

In the current flow of plastics for example only 2% of all plastics is classified as closed loop recycling, see figure 28 . Closed loop recycling describes recycling of plastics in same or similar quality products (Ellen MacArthur Foundation, 2016). A closed loop drastically decreases the leakage of materials into natural systems and other negative externalities. To prevent this negative effect, closed loop recycling will become more prominent (see figure 29).

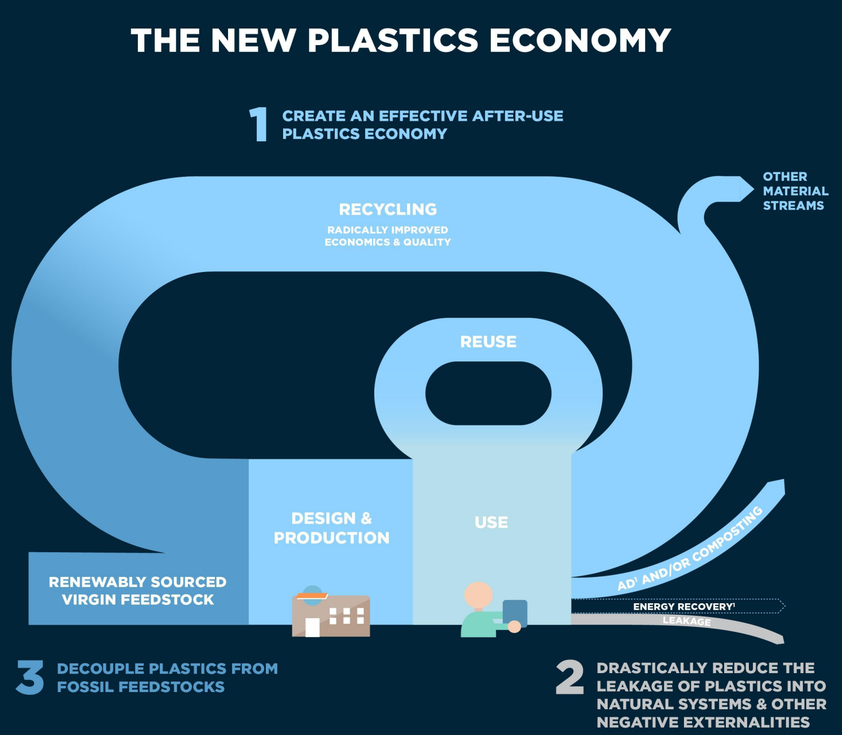
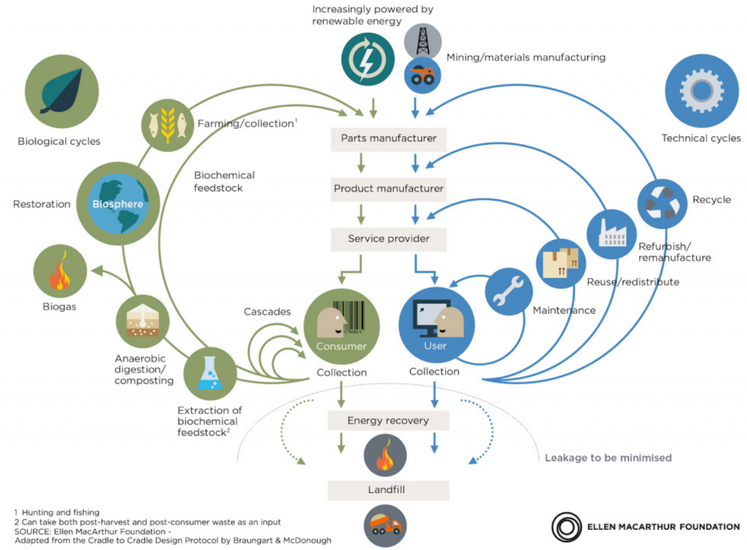


Figure 29: Circular economy
Figure 30: Technocycle and biocycle



Technocycle and biocycle

The flow of resources in the circular economy is depicted in the butterfly diagram in figure 30 which describes two main cycles. The green loop contains renewable or organic materials whereas the blue loop contains the technical materials. The main difference is that materials in the blue loop are mined instead of harvested which results in high energy consumption and heat generation. Although they seem like two separate cycles, they are intertwined which makes reprocessing even more difficult. Circular products therefore need to keep the maintenance and end-of-life scenario (EOL) in mind. Making use of single materials that are easily repairable and preferably modular. If multi-material products are required, these materials need to be easily separable to allow better recyclability.

In order to keep materials in the loop, the usage stage is extended. Circular products are designed for contin-use in order to extend the usage phase and therefore the lifetime of the product. This means that it should be designed with multiple stakeholders in mind. There are three main principles to keep materials in the loop during the usage stage:

1. **Reuse**
   This is the preferred option to keep resources in the loop and prevent material degradation. Environmental impact per usage gets smaller with more cycles.

2. **Repair & Remanufacture**
   If a product can not function anymore it should be the first priority to repair it instead of discarding it. Applying design for repairability through the principle by modularity is beneficial to keep products in the loop longer.

3. **Recycle**
   If products can not be repaired, recycling is the best option. This way resources can be repurposed.

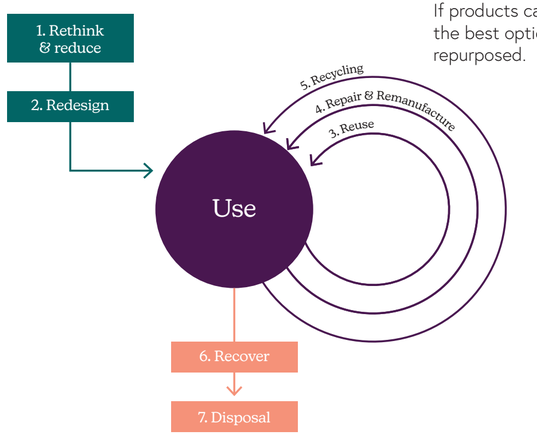


Figure 31: Reduce, reuse, recycle

Key Insights

Conclusion

This section describes the characteristics of a circular product and system. These principles have been applied to the context of the project to make them actionable and better fitting in the context described in chapter 3.1 to chapter 3.4. These actionable requirements are described as the design fundamentals, presented in chapter 2.2.

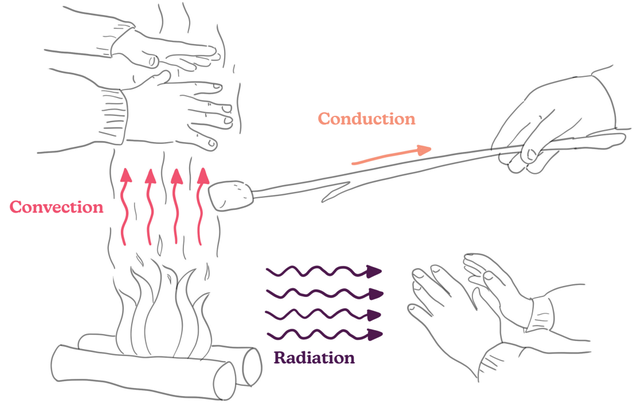
Circular economy

- Shifting from a waste-based paradigm to a resource-based paradigm becomes increasingly important to sustainably deal with the resources of our planet.
- The product lifecycle should follow the three main principles of circular scheme: Reuse - Repair - Recycle.
- Design for repairability through the principle of modularity is beneficial to keep products in the loop for longer.

3.6 Material Selection

In this section both the insulation and the case materials are defined. Hemp is used for insulation material because of its great properties and sustainable performance. Recycled Polypropylene was found to be best fitting because of its versatility and durability.

Figure 32: Conduction, Convection and Radiation



Insulation material

A passive cooling solution is chosen, as described in chapter 3.1. Passive cooling does not require any energy input, instead it requires an insulation layer that prevents the passage of heat from one conductor to another (Miriam Webster, z.d.). Preventing heat transfer works differently for all three methods of heat transfer. Each method requires different material properties, as discussed in chapter 3.8, the following thermal properties need to be considered when selecting the proper material:

1. Conduction

Specific Heat Capacity (C)
The ability of a material to absorb heat.

Thermal conductivity (k)
The ability of a material to conduct heat.

2. Convection

Heat Transfer Coefficient (h).
The ability to convect heat through a fluid or gas.

3. Radiation

Emissivity (e)
The ability of an object to radiate heat.

4. Additional properties

Density, keep the density low to keep the weight low.
Production Footprint, keep as low as possible.
Recyclability, material needs to be recyclable
Price, keep the price as low as possible.

Principle of insulation

Most insulating materials benefit from the air pockets in the material. These small pockets eliminate the convection flows, which drastically slows down the heat transfer. The commonly used insulator styrofoam (EPS) is a great example of this, but examples can also be found in nature. Otters and seals for example have two layers of fur. A coarse layer of guard hairs isolate a finer layer of under hairs from the outside. The fine structure creates many air pockets that keep the heat in (Ask Nature, 2021).

The bodies of otters and seals have to work to keep their temperature constant and prevent heat transfer to the environment. This is opposite to the project objective to prevent heat from entering the system. Therefore, a coolant is used inside the system to keep the temperature low for longer. Using coolant as a variable gives room to optimize the cooling for specific products and logistics. The thermal performance can be tweaked by the type and amount of coolant used. This needs to be determined based on the weight of the product and its specific heat capacity (Dieckmann et al., 2019, p. 100360).
In addition, the empty volume (dead space) in the cooling compartment should be kept minimal and the cooling compartment should be free from gaps to prevent warm air from entering the system.

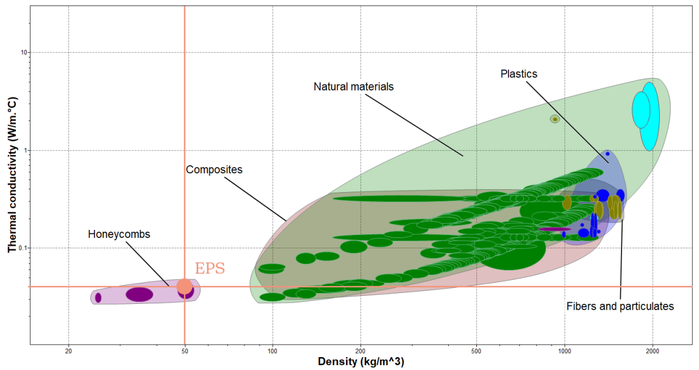
Figure 33: Material plot CES
Figure 34: Selected materials

Initial material selection

In CES Edupack the following material families were plotted on thermal conductivity and density. Non-biodegradable materials were filtered out of this selection. The performance of honeycomb structures stands out as it is comparable to that of EPS. Based on this plot a selection of potential materials was made.

Selected material categories

Based on the scope and market opportunity, described in chapter 3.1, both the composites and the cardboard honeycombs are eliminated. This results in the following materials that will be compared, see figure 34. Air is added to the list because of its insulative properties.



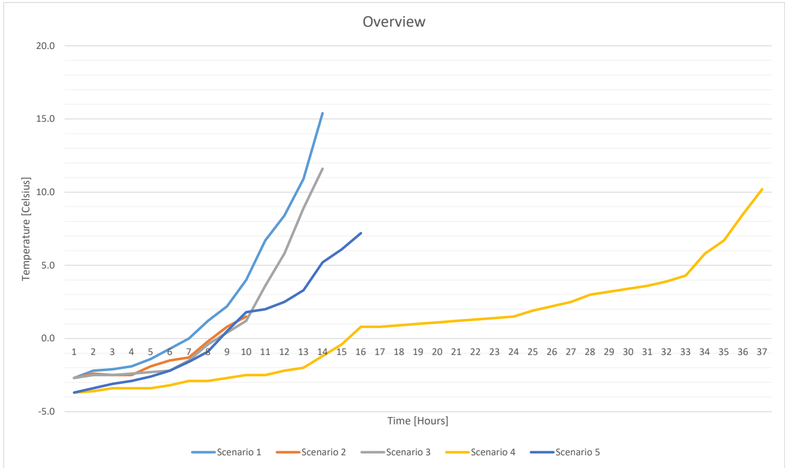
Name	Origin	Base	Material Type	Recyclability	Biodegradable	Thermal c...	Cost [€/KG]	Density [KG/m3]	CO2 Foo...
Mycelium	Natural	Plant	Fibrous	Poor	Excellent	0.05	€2.80	100	0.31
Sheepwool	Natural	Animal	Fibrous	Poor	Good	0.2	€1.77	1280	15
Hemp	Natural	Plant	Fibrous	Poor	Excellent	0.2	€0.56	1470	1.52
Jute	Natural	Plant	Fibrous	Poor	Excellent	0.25	€0.11	1440	2.69
Flax	Natural	Plant	Fibrous	Poor	Excellent	0.2	€0.65	1420	0.42
Air	Natural		Gas	Excellent	Excellent	0.024	€0.00	1.225	0

Excluded from the list

Sheep Wool, although sheep wool is an excellent insulator, it is excluded from the list because of its smell. Samples of wool insulation have been ordered en tested, from that it has been concluded that the smell is too prominent to ignore. Especially when packing food, this is an unpleasant experience for the customer.

Mycelium, this wonder material is rising in popularity. However, due to its infancy it is expensive to produce. Therefore, it is found to be too expensive for this selection.

This results in the following materials that made the final list: Both hemp and flax fibers and air are selected.



Air vs fibers

A test has been conducted where concepts developed based on these materials, see chapter 3.11, have been compared, see appendix C. Figure 35 shows the results from this test with a substantial difference in insulative performance of the fibers (scenario 4) and the air insulation (scenario 2, 3 and 5). Therefore, it is decided to continue with fibers in the selection process.

Figure 35: Testing results comparing air vs fiber insulation

Hemp vs flax

In terms of insulative performance these two materials show similar properties. In addition, both materials can be sourced in the Netherlands. In an interview with David Kasse, advisor at Flax & Linnen NL, states that these materials are quite similar except for the fact that growing hemp does not require any fertilizers or pesticides. Therefore it can be sourced organically, see appendix L . Based on this, hemp is considered the best fitting and most sustainable insulation material for this use case.

Case material

The case material needs to protect the food and insulation layer during transport. The material needs to be durable, it should be able to withstand rough usage. Small cracks or scratches should not cause failure to function. In addition, the material should also be considered a good conductor as each layer adds to the insulative performance of the Boks.

1. Mechanical properties

Yield strength
The elastic limit: The maximum stress a material is able to develop without causing plastic deformation.
A high yield strength is favorable, since the material will be able to absorb more stress before plastic deformation occurs.

2. Impact properties

Fracture thoughness
A material's ability to resist further fracture once a material contains a crack.
A high fracture toughness is important to prevent part failure initiated by damage.

3. Thermal properties

Thermal conductivity
The ability of a material to conduct heat.
A lower thermal conductivity is favorable as the material conducts less heat.

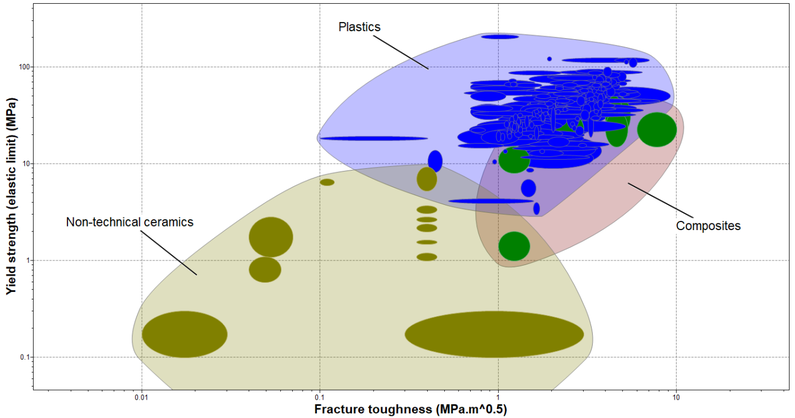
4. Additional properties

Density, keep the density low to keep the weight low.
Production Footprint, keep as low as possible.
Recyclability, material needs to be recyclable
Price, keep the price as low as possible.
Producibility using injection molding, this allows the design to be produced in large quantities with excellent dimensional freedom

Initial selection

Plotting these characteristics leads to the following plot in figure 36, which shows that plastics perform best for the given use case.

Zooming in on this material family shows both Polypropylene or Polyethylene as potential materials. These materials are also recommended by Caroli Buitenhuis, bioplastics expert at green serendipity, see appendix M. Both materials are being used for packaging purposes and are approved for food contact, they are proven in the context. Besides being perfectly recyclable, they are also able to withstand moisture, chemicals, and heat which makes them durable in the given context.

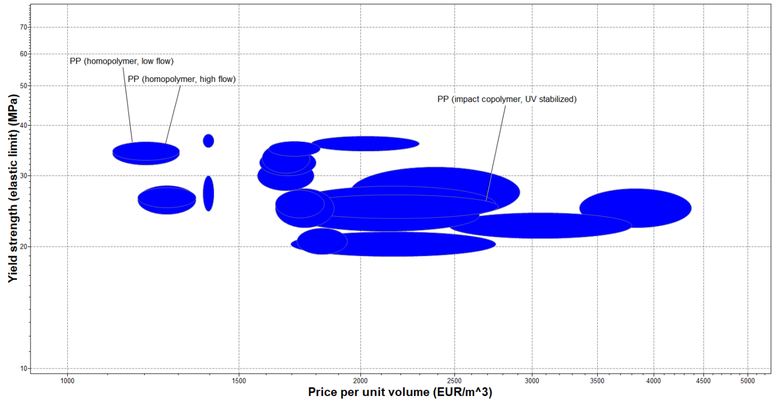


Polypropylene

Polypropylene is found to be the best fitting material for the outer case as it performs better on the requirements. Since PP is perfectly recyclable it is chosen to incorporate recycled content in the material. This reduces the need for virgin materials. Currently it is advised to test with PP homopolymer, to test the fit and performance in the context. If needed, it can for example be chosen to switch to a more UV resistant PP alternative, see figure 38.

Figure 36: Initial material selection
Figure 37: Polypropylene vs polyethylene comparison
Figure 38: Polypropylene material types

Name	Yield Strength	Fracture Thou...	Thermal co...	Density	Price / KG	Embodied en...
Polypropylene	32.9	2.11	0.205	899	1.24	1.06
Polyethylene	26.2	1.52	0.461	952	1.4	0.898



Key Insights

Material analysis

- Hemp is the best fitting material to use for insulation.
- Recycled Polypropylene, is the best fitting material for the outer case.
- The empty volume (dead space) in the cooling compartment should be kept minimal.
- The cooling compartment should be free from gaps to prevent warm air from entering the system.
- The thermal performance can be tweaked by the type and amount of coolant used. This needs to be determined based on the weight of the product and its specific heat capacity.

3.7 Circular Business model

In this section the best fitting business model is generated. After various case studies it is concluded that a transitory model with a digital rewards marketplace fits the use case best. The designed model describes the webshop only paying for the usage, while Goodcase Packaging remains the owner of the products. A discount reward is designed to incentivise both the consumer and the webshop to keep the product flowing.

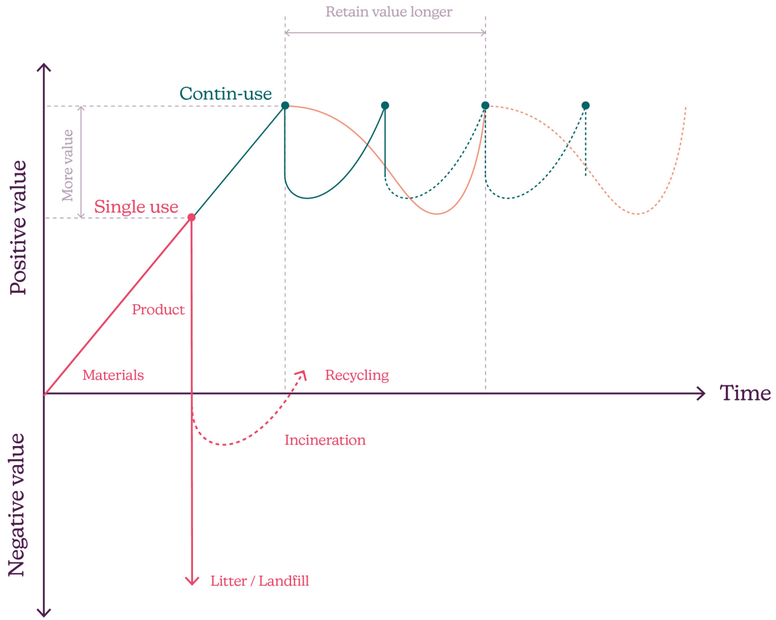
Products that flow

Products that flow describe the category of fast moving consumer goods (FMCG). They include mass produced products that are cheap and most of all have a short lifespan. This combination results in a large amount of waste. The main problem with the consumption of these goods in modern day society is the immediate value drop after consumption.

This becomes strikingly apparent with packaging material. Grocery stores are filled with individually packed vegetables. Packaging material is sourced, produced, stored and subsequently used for a very short amount of time. All in order to be recollected and recycled in the best case scenario, see red line in figure 39. In this example, the problem is not that the product fails. Consumers bought the contents of the packaging, not the packaging itself. It is just no longer usable for them and therefore it does not represent value to them. Single use packaging feeds and maintains an unhealthy relationship with the resources our planet has to offer. This is different in the fashion market, where consumers buy garments which are used over a longer timespan. In fast fashion, the value drops faster since new collections are dropped once every week (Buying Better, z.d.) . Slow fashion retains its value longer over time, which makes it much more interesting for reusing. This is becoming more apparent with initiatives like Vinted which works exceptionally well for luxurious garments (Gardetti & Coste-Manière, 2020).

These examples show that opportunities differ drastically based on the product, market and the target group. In addition, it needs to be considered that packaging is a product that consumers generally do not buy and therefore less value is attached to it. Envisioning the packaging as a reusable product by adding more value to it could help improve the product-consumer relationship.

Figure 39: Fundamentals scheme
Figure 37: Greenwheels
Figure 38: MUD Jeans



Case studies

With this focus various business models could be generated. The models below are based on existing cases. They are divided over perpetual and transitory models. Perpetual models such as subscriptions describe a returning customer and therefore a returning revenue at a fixed interval (e.g. week, month, year). Whereas transitory models are characterized by a fee that is paid upfront by the customer. This fee can be (partially) returned afterwards. Some of the transitory models have potential to be translated into subscription based models depending on the product and target audience.

Perpetual models

Performance

- Customers only pay for the actual usage of the product. The company remains the owner and service provider of the product. **Example: Greenwheels**
- Customers pay a fixed fee per month and receive the product in return. They are free to use the product as frequently as they like. **Example: Miele washing machines**

Towards ownership

- Customers pay a fixed fee per month and receive the product in return. They are free to use the product as frequently as they like. After a certain time frame the customer pays a small fee for the product and becomes owner of the product or chooses to resend it to the company where it can be recycled. **Example: MUD Jeans**

Transitory models

Flow management

- Customers pay a deposit upfront and get a refund once the product is returned. Here the product is representing a fixed monetary value.
  Example: Statiegeld in the Netherlands

- Customers receive the product for a small fee, the product becomes a token for the next order at the same company. Returning one or more products creates perks for the next sale. Here the product represents a discount on the next sale.
  Example: Lush return program

Flow ecosystem

- Customers receive the product for a small fee, the product becomes a token for the next order at an (online) marketplace with multiple companies. Returning one or more products creates perks for the next sale.
  Example: Packback

- Customers receive the product for a small fee. It is not mandatory to send the product directly back to the company. Customers can save and bundle the products or send it to others. The customer is even free to give the product another purpose.
  Example: RePack

Reverse logistics

- Customers buy a product and return it at a pick up point at the end of its lifespan. The products are subsequently collected and recycled into new ones.
  Example: Auping Circular matress

Figure 40: Statiegeld Nederland
Figure 41: PackBack
Figure 42: Auping

Reward vs deposit

Various aspects of these models can be applied to the business model of Goodcase Packaging. When plotting these cases it becomes clear that with a packaging focus transitory models are currently the preferred option, see figure 43. Both reward and deposit models are currently applied within this section.

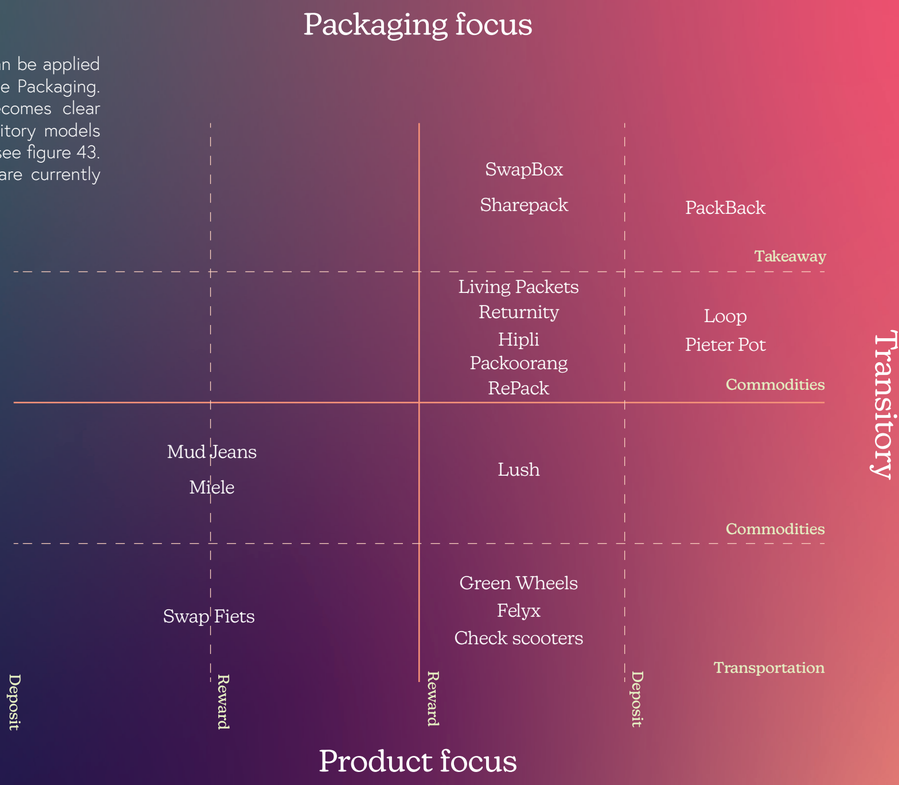


Figure 43: Case studies plotted

Rewards vs deposit

In order to determine which approach fits the user case best, rewards and deposits are compared in this section.

Deposits are a solid tool to incentivise the consumer to return the product, it is directly related to money which is one of the main motivators for action. In addition, deposits are a proven and still relevant solution in the Netherlands given the use in recollecting of waste streams (Ministerie van Infrastructuur en Waterstaat, 2021).

From a webshop perspective deposits work best with recurring customers and subscriptions, such as Pieter Pot, where the deposit could be distracted from the next purchase. Here the processing and maintenance happens in house, so the deposit transfers only between the webshop and their customers.

As discussed in the stakeholder analysis in chapter 3.4, the box flows among three main stakeholders. This makes the situation more complex as it results in shifting money from one stakeholder to the other. This creates unwanted complexity in cash flow for both Goodcase Packaging and the webshops. Therefore, it needs to be considered to remove the direct link to the monetary value of the deposit.

The main benefit of rewards is their flexibility. The reward can represent different types of value which can easily be adapted to the needs of the customer. As a result, stakeholders are no longer shifting actual money. They shift value in the form of a digital token. Each token could represent a different value for each connected webshop. This forms the basis of a digital marketplace with all connected webshops. The customer has the complete freedom to decide for themselves where they cash their token.

The rewards approach is favored over the deposit approach as it disconnects the reward/ deposit and its direct monetary value. Favoring a digital token over money decreases complexity for both Goodcase Packaging and the connected webshops. In addition the rewards approach opens opportunities to create an online marketplace, which could be an extra incentive for webshops to participate. The marketplace could be a good way of customer acquisition.

Value flow

With every returned box, the customer gets a digital token. This token can be redeemed at associated webshops on the digital marketplace. Webshops can determine themselves what reward the digital token represents in their webshop. Involving the webshop in the reward scheme allows them to adapt the reward to their individual customers' needs as they know their audience the best. In addition it incentivises the webshop to clearly communicate the intended behaviour with the reusable to the customer.
The more boxes returned from the customer to Goodcase packaging, the more discount the webshops receive, as described in chapter 3.9. This incentivises both the webshop and the customer to keep the product flowing.

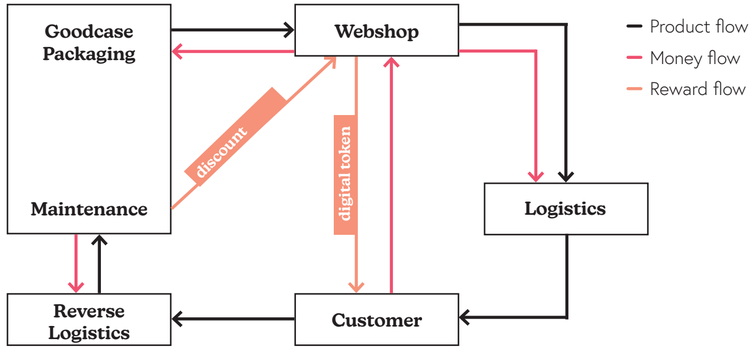


Figure 44: Value flow diagram

The proposed business model canvas is described in figure 45:

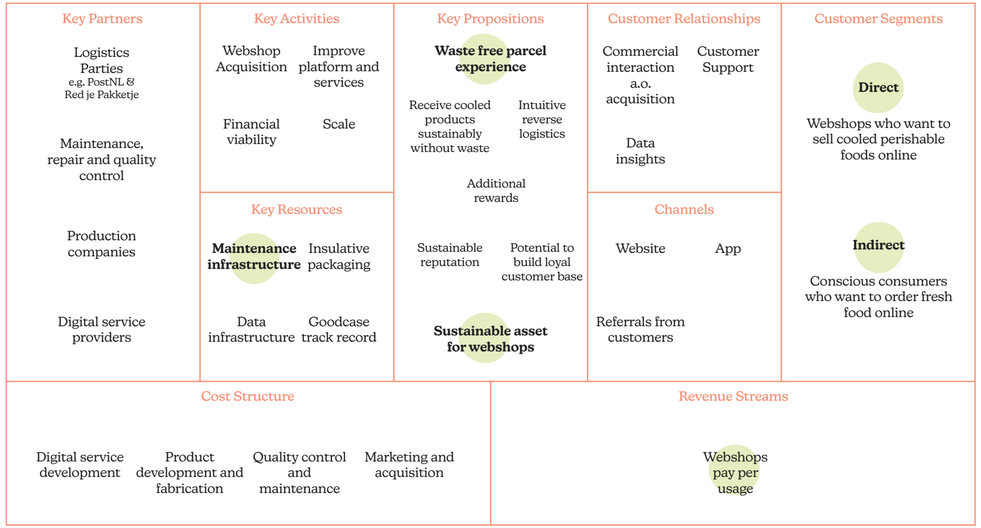


Figure 45: Business model

Key Insights

Circular business model

- Opportunities differ based on the product, market and the target group.
- It can not be neglected that packaging is a product that consumers generally do not buy and therefore less value is attached to it.
- Envisioning the packaging as a reusable product by adding more value to it could help improve the product-consumer relationship.
- Retaining that value over a longer time could eventually lead to longer lasting products.
- Transitory models are more common than perpetual models in the case studies with a packaging focus.
- A rewards approach is favorable over a deposit approach given the use case.
- The webshops need to have freedom to determine the reward, as they know their customer best.
- Involving the webshops in the performance rewards incentivises them to incentivise their customers.

3.8 Thermodynamic analysis

In this section the thermodynamics are researched. From this analysis important parameters and equations are elaborated. These form the basis to the parametric model described at the end of this chapter.

Thermodynamics describe the thermal behaviour of systems over time. It provides insights into the conversion of energy from one form to another and the direction of flow of heat. Its laws are universal, meaning it is applicable to all systems everywhere in the known universe.
The field of thermodynamics comprises four main laws which are described below with support of their fundamental physical laws.

0th law

If system A and B are both in thermal equilibrium with a system C, they are also in thermal equilibrium with each other. Equilibrium is a state where certain properties, such as temperature, volume or pressure, remain the same across a system. So, in thermal equilibrium there is no energy transfer.

1st law

The change in the internal energy (ΔU) of a system is equal to the amount of energy added (Q) by heating the system minus the amount lost as a result of the work done (W) by the system to its surroundings.

$$\Delta U = Q - W$$

2nd law

The entropy in an isolated system will increase over time as it arrives at a state of thermal equilibrium. Entropy is referred to as the inherent disorder of a system. The more disordered the system the higher its entropy. Time will increase entropy as energy spreads out across the system, until it arrives at thermal equilibrium the state with highest entropy. Therefore, heat always flows from a warmer system to a colder system because that leads to an increase in entropy. Heat flow from cold to warm is impossible.

3rd law

As temperature approaches absolute zero (-273.15 Celsius), the entropy of a given system approaches a constant value. This law is less relevant for this project since temperatures in the use case do not get near this point.

Conservation of energy

This law states that the total energy within an isolated system remains constant. This is based on the fact that energy can not be created nor destroyed. It can only be transferred from one form to another. For example the transformation of kinetic energy into thermal energy. In the following equation (ΔE) the energy added to the system through heating, (Q) is the heat exchanged through the boundary and (A) is the area of the boundary.

$$\Delta E + \int_S Q \, dA = 0$$

Latent heat

This describes the amount of energy released (or absorbed) by a substance during the change of phase without changing its temperature. (Q) is the amount of energy released or absorbed during the change of phase [kJ]. (m) describes the mass of the substance [kg] and (L) is the specific latent heat of the substance [kJ/kg].

$$Q = m * L$$

Specific heat capacity

The amount of heat or thermal energy that needs to be added to the system in order to increase the temperature of one unit of mass of substance by one unit. (ΔQ) is the change of energy [J], (m) is the mass of the substance [kg], (C) is the specific heat capacity [J/kgK] and (ΔT) is the change in temperature [K].

$$\Delta Q = m * C * \Delta T$$

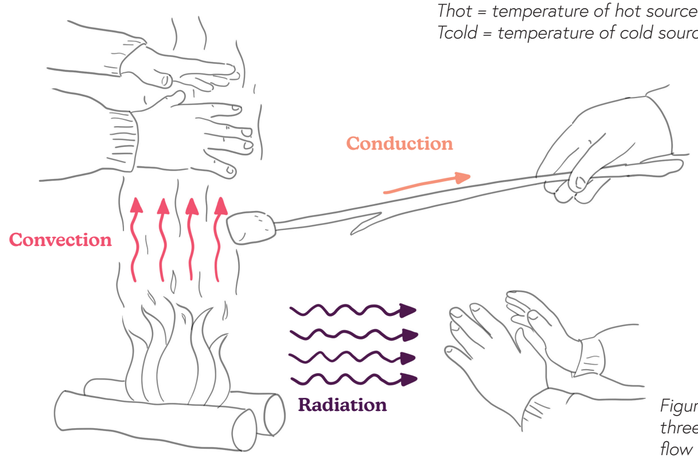


Figure 46: The three types of heat flow

Three modes of heat transfer

Heat can transfer in three different ways depending on the medium it travels through.

1. Conduction via solid contact

The transfer of heat (internal energy) by microscopic collisions of particles and movement of electrons within a body.

$$q(t) = \frac{k*A}{L} (Thot(t) - Tcold(t))$$

q = netto heat flow over time
k = thermal conductivity
A = surface area
L = distance of heat travel
Thot = temperature of hot source
Tcold = temperature of cold source

2. Convection via fluid contact

The process in which heat is carried by the bulk movement of a fluid/gas.

$$q(t) = h*A\ (Thot(t) - Tcold(t))$$

h = heat flow coëfficient

3. Radiation via electromagnetic waves

The emission or transmission of energy in the form of waves or particles through space or through a material medium.

$$q(t) = \varepsilon * \sigma\ (Tobj(t)^4 - Tenv(t)^4) * A$$

ε = emissivity of material
σ = stefan boltzman constant
Tobj = object temperature
Tenv = environment temperature

Thermal resistance

The thermal resistance (R) is the material's ability to resist heat flow. It is connected to thermal conductivity (k) and the material thickness (d). The larger the thickness, the higher the thermal resistance.

$$k = q \frac{d}{\Delta T}$$

$$R = \frac{\Delta T}{q} = \frac{d}{k}$$

Essential parameters

Eventually all systems reach equilibrium after a certain period of time. The objective for this project however is to extend this period in such a way that it is functional in the use scenario described in chapter 3.3. In order to do so, an insulating barrier is required. In this section important parameters will be assessed which leads to clear selection criteria for the material analysis described in chapter 3.6.

Material parameters

1. **Specific Heat Capacity (C) [J/kgK]**
   This value should be as high as possible. A higher value requires more energy to be put in the system in order to raise the temperature.

2. **Thermal conductivity (k) [W/(mK)]**
   The ability of a material to conduct heat. This value should be kept as low as possible. This prevents heat from flowing from the environment into the cool compartment.

3. **Heat Transfer Coefficient (h) [W/(m2•K)]**
   The ability to convect heat through a fluid or gas. This value should be kept as low as possible. It prevents heat from flowing from through air or fluids within the cool compartment.

Emissivity e [-]
The ability to radiate heat. This value lies between 0 (reflector) and 1 (radiator). A reflector, for example aluminum, prevents heat from passing by reflecting the electromagnetic waves. A lower value is favorable for insulation.

Physical parameters

5. **Boundary surface area (A) [m^2]**
   This value should be kept as low as possible. A large contact area to the environment will increase the heat transfer between the inside and the outside. The optimal surface to volume ratio needs to be determined while keeping in mind the requirements for the contents.

6. **Mass (m) [kg]**
   The box should be easy to handle, even when it's completely filled with products. From an ergonomic perspective the box should add as little weight as possible, whereas this decreases the potential heat absorption. This parameter needs to consider the conflicting wishes to best fit the use scenario.

Material thickness (d) [m]
The larger the thickness, the higher the thermal resistance. A thicker boundary layer will result in a better insulating performance. However, it will result in extra mass added to the system, so this variable should keep in mind the overall ergonomics.

Environmental parameters

8. **Cool temperature (Tcold) and Environmental temperature (Thot) [K]**
   The larger the difference the longer it will take until equilibrium is reached. Thot needs to be regarded as the extreme scenario. Which is an average constant temperature of 27 °C according to ISTA (Thermal Standards - International Safe Transit Association, z.d.). Tcold depends on the type of product, but is preferably frozen at -18 °C to increase the time until equilibrium state is reached.

9. **Threshold temperature (Ttres) [K]**
   The temperature that should not be exceeded during transport. This depends on the type of products it is transporting. Legal temperature thresholds for meat products should not surpass 5 °C (Food and Drug Association, 2021). Product deterioration is accelerated during exposure to temperatures above these limits. Exponential bacterial growth is initiated which jeopardizes food safety (Dieckmann et al., 2019, p. 100360). Meat products can be perfectly shipped frozen. However, for plantbased the threshold limit could be up to 14°C, as described by Gertjan Kuijk from upside.

Thermodynamic model

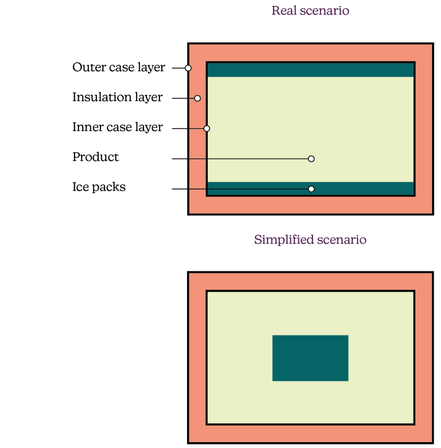
How do all these parameters work together in a parametric model? In this section the process of building the model is described with assumptions and simplifications. The parametric model is presented in appendix D.

- The main simplification is that the product layer is modelled around the ice, see figure 47. This is unrealistic, as the product will never completely surround the whole ice or the other way around. This simplifies the model as heat flow from the ice directly to the case can be neglected.

- With this simplification it is expected that the efficiency is a bit higher compared to the real world since the ice cools only the product. This deficiency needs to be tested so an efficiency factor can be build in the model.

- The outside temperature is modelled as a constant. This is unrealistic as temperature profiles are never constant.

- There is no empty space in the model to decrease complexity. However, it is unrealistic to have a real world scenario where the whole box is completely filled with products.



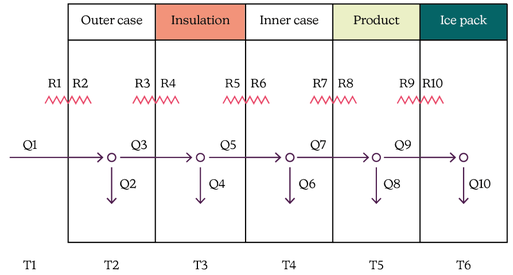


Figure 47: Simplifications and assumptions
Figure 48: Schematic heat flow of thermodynamic model

With this model the cooling time can be calculated for different scenarios. Results from that analysis are presented in table XX. Please note that actual results might differ based on fluctuating temperatures, product and type of coolant.

Outside temperature [Celsius]	Product weight [kg]	Time till 5 degrees [Hours]	Packs required [No.]
27	3	36	8
	2	35	10
	1	36	13
20	3	35	5
	2	37	7
	1	36	9
15	3	36	2
	2	37	4
	1	37	6
10	3	49	1
	2	36	1
	1	37	3

Table 6: Thermodynamic model output for different scenarios

BOKS performance testing

The performance of BOKS is tested to compare it to the parametric model. The complete test report can be found in appendix C. The test was executed with 1.2 kg of food and 5 ice packs. As can be seen by the yellow and orange lines in figure 49 BOKS kept these frozen products (-18 C) under 5 degrees Celsius for at least 32 to 39 hours depending on the type of product. Compared to the calculated time of 24 hours from the parametric model (green line), this is a large discrepancy. The parametric model needs to be revisioned in order to make it resemble real world data more.

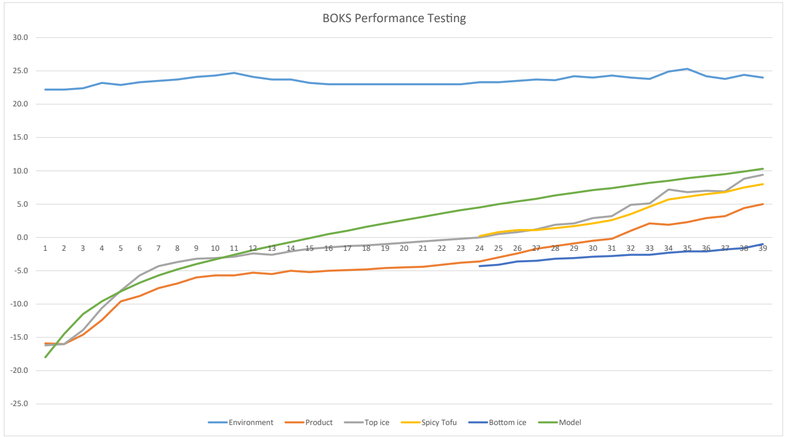


Figure 49: Results of performance testing

Improvements and considerations

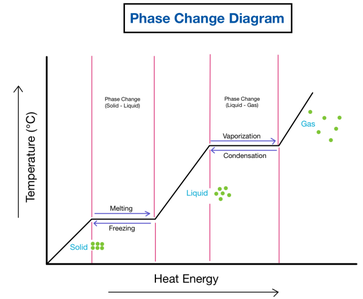
Time dependent heat capacity

The path of the green line in the parametric model is fluent almost like a root function. Whereas the path of the measured data resembles the shape of a phase change diagram, see figure 50. This difference is due to the input data of the model. The heat capacity changes based on the phase and the temperature of the products and ice as visible in table 7. Incorporating this time-dependency in the model is expected to alter the path into the shape of a phase change model and therefore make it more realistic.

Figure 50: Performance testing setup

Ice	Water	Vapour
2.108 [kJ/kgK]	4.187 [kJ/kgK]	1.996 [kJ/kgK]

Table 7: Specific heat capacity of ice water and vapour



Loosely and densely packed

The difference between the two products in cooling time is quite big. This is due to the way the product is packed. In order to give webshops the best insight on what they can expect, a switch would be required to select if the products are packed loosely or densely.

Key Insights

Thermodynamics

This model provides an insight into the thermal performance of the Boks. Since the model is completely parametric, it allows complete configurability which is favorable to find the optimal configuration for different use cases and environmental conditions. After validation with real world testing it was found that the accuracy is not high enough to represent the real world data accurately. The accuracy will be improved by the proposed measures.

3.9 Cost analysis

In this chapter the financial model is elaborated. Input data corresponds with data from the thermodynamic model and the LCA tool, described in chapter 3.8 and 3.10 respectively. The model provides insight into how each parameter influences the financial results and gives control to simulate different scenarios. Important improvements and their overall influence are assessed. From the analysis it was found that a competitive selling price of €3.19 per trip is achievable with a profit margin of 40% and a return rate of 80%. The reward system is designed based on the return rate and the amount of orders from the webshop.

Assumptions

The model describes the flow of boxes in the closed loop system. Educated assumptions are made in order to make the system work, the complete overview of the system and all assumptions is described in appendix N. In this section most important assumptions are described.

- **Cost price €15**
  This assumption is an estimate. The effect of different cost prices is assessed in the improvements and considerations in this chapter.
- **Lifetime 100 cycles**
  This assumption is based on the life expectancy of beer crates wvhich lies between 10 and 20 years, with an assumed flow once every two months (Business Logistics, 2018).
- **Return rate 80%**
  This educated estimation is based on various interviews with ecommerce companies, see appendix G.
- **Average flow time 20 days**
  For Goodcase packaging it is beneficial if the BOKS does not stay long at the webshop, so the webshop buys in minimal bulk depending on its average amount of orders. BOKS is assumed to stay at the webshop for 7 days. Subsequent logistics lasts 2 days which gives the consumer 9 days to drop it off at the local supermarket. Reverse logistics and cleaning is assumed to last another 2 days. This accumulates to a total of 20 days.

Revenue per trip

The buildup of the cost price in figure 51 per trip works as follows.

- The Packaging costs are calculated making use of the cost price and the lifetime of BOKS and the ice packs.
- Logistics to webshop are calculated as bulk shipment.
- Reverse logistics are also calculated as bulk shipment.
- Cleaning includes inspection and washing in industrial installation.

The output price of €3.19 is comparable to its competitors. As concluded from the supplier interviews, see appendix B, the Recycold insulation was the preferred option at a selling price of €3.00 (Recycold, z.d.). This makes BOKS a competitive alternative, which could financially become more interesting with the kickback system.

Packaging	0.21
Logistics to webshop	0.26
Reverse logistics	0.54
Cleaning	1.27
Cost price	2.28
Margin (40%)	0.91
Total per trip	**3.19**

Figure 51: Revenue per trip

Reward system

A reward system is designed in order to gain more insights in the effect of the rewards. This kickback is a performance discount which rewards the webshops when their customers resend BOKS to Goodcase Packaging. The higher the return rate, the higher the discount will be. In addition, the price per BOKS differs based on the amount of BOKSES a webshop sells per year. For this to work, the webshops are divided over 5 categories. Initial focus lies on the first 4, mega could be interesting for future collaborations.
Table 8 shows the categories and examples of webshops in the field of sustainable food. The customer is free to decide whether they choose for BOKS. Therefore the amount of orders in the table is estimated to be around 20% of the total yearly volume of the webshop. This percentage is an estimate and will likely differ per customer segment.

Startup	Small	Medium	Big	Mega
0 - 100 Orders / Year	101 - 500 Orders / Year	501 - 1500 Orders / Year	1501 - 3000 Orders / Year	3001 + Orders / Year
Freggies Botanic Bites Jaapie Zwamburger	Haagse Zwam Krekerij Upside Falafval Friendly fish Knafwortel Karma Kebab	5th season fruits BUMI Dutch Weed Burger Grünten Farmhouse int.	Meet Jack Willicroft	Hellofresh Pieter Pot Ekoplaza Albert Heijn Jumbo

Table 8: Webshop classification

Based on these segments the kickback can be designed. The price is dependent on both the return rate and the amount of orders. Each tier in the amount of orders and each 5% increase in return rate will subtract a factor 0.01 from the price. In total this could lead to a max €0.22 saving per trip for the webshop as visible in table 9.

For startups and small webshops this kickback might be less interesting as visible in table 9. For larger webshops the amounts become more significant. The initial strategy could focus on medium and big webshops. However, finding out if these amounts are sufficient enough to switch to BOKS requires further investigation.

	% Return	<74	75 - 79	80 - 84	85 - 89	90 - 95	95 - 100
Type	Factor	1.01	1	0.99	0.98	0.97	0.96
Startup	1	3.22	3.19	3.16	3.13	3.09	3.06
Small	0.99	3.19	3.16	3.13	3.09	3.06	3.03
Medium	0.98	3.16	3.13	3.09	3.06	3.03	3.00
Big	0.97	3.12	3.09	3.06	3.03	3.00	2.97

	Deliveries	Min. discount at 75% returnrate	Max. discount at 100% returnrate
Startup	50	-	31.90
Small	300	31.90	158.21
Medium	1000	79.94	236.04
Big	2500	239.23	548.62

Table 9: Kickback system
Table 10: Discount per webshop class

Improvements and considerations

Most important parameters are further investigated in this section. By assessing how they affect other relevant parameters, a list for further improvements can be generated. For each parameter the netto result in year one is assessed. This netto result does not take into account any overhead cost and hypothetical funding. This gives an unrealistic result, most costs of starting up are made in the first years. However, this way provides insight into the individual effect on the operational cost.

1. Cost price

Increasing the cost price of one BOKS by €5 adds €0.07 to the selling price in the current configuration, see table 11. Between €25 and €30 the netto results tips from positive to negative. Keeping the cost price as low as possible is an effective parameter to keep both the selling price and the costs low.

2. Flowtime

The flowtime is the total time it takes to make one loop. A shorter flowtime means less required BOKSES. This means a lower investment in production which has a positive result on the netto result. From this analysis it becomes clear that the flow time should be kept as low as possible, see table 12. In addition a flowtime between 30 and 35 days means that a tipping point is reached in the current configuration.
Keeping the flowtime as low as possible is one of the major challenges to make the system work.

Table 11: Costprice modifications
Table 12: Flowtime modifications

Cost price [€]	Selling price [€]	Year 1 Netto result [€]
5	3.05	6.403
10	3.12	5.030
15 (current)	3.19	3.656
20	3.26	2.283
25	3.33	909
30	3.40	-463

Flowtime [days]	BOKSES required [No.]	Year 1 Netto result [€]
10	171	6.482
15	257	5.069
20 (current)	342	3.656
25	428	2.244
30	514	831
35	599	-581

3. Return rate

Table XX shows that altering the return rate shows that, from a financial perspective, the optimal return rate lies at 78%. At lower rates the costs for producing new BOKSES is higher, whereas at higher rates the costs for reverse logistics and cleaning become higher. Keeping the costs for reverse logistics and cleaning low will elevate the optimal return rate.

Another parameter affecting the netto result is the kickback system. The right column in table 13 describes that the netto result in year one without the kickback system. Without the discounts the optimal return rate increases to 87%. The most effective kickback configuration needs to be analyzed further, while keeping in mind this effect on the netto result.

Return rate [%]	BOKSES required [No.]	Year 1 Netto Result INCL kickback [€]	Year 1 Netto Result EXCL kickback [€]
50	548	2.390	2.234
60	457	3.293	3.137
70	391	3.765	3.609
80 (current)	342	3.656	3.812
85	322	3.531	3.843
90	304	3.368	3.836
95	288	3.174	3.798
100	274	3.110	3.734

4. Growth rate

The growth rate for each year results in an incremental increase in yearly netto result in the current configuration, see table 14. Due to the fact that less investments are required in the production of new products the yearly costs stay low. Extending the lifetime will contribute positively to the incremental increase in netto result. The lifetime is another crucial parameter that needs further investigation to make the system work.

Growth rate [per year]	Year 1 Netto Result [€]	Year 2 Netto Result [€]	Year 3 Netto Result [€]	Year 4 Netto Result [€]
200-200-200	3.656	18.034	45.042	99.447
200-250-300	3.656	18.034	48.682	135.770
200-300-400	3.656	18.034	52.339	179.408

Table 13: Returnrate modifications
Table 14: Growthrate modifications

5. Reverse logistics

In the current scenario, the reverse logistics are unrealistically defined at 72 BOKSES per reverse trip from a specific dropoff location. As a result the costs are only €0.54 per BOKS per trip. This number is unrealistic given the fact that there are only 274 BOKSES flowing with a flowtime of 20 days. This might become realistic once BOKS becomes an established packaging. Changing these amounts drastically increases the selling price as visible in table 15. This shows that the amount of BOKSES per reverse trip needs to be as high as possible in order to keep the price low. In order to do so, substantial scale is required.

No. BOKSES reverse	Selling price [€]	Year 1 Netto Result [€]
10	7.89	8.390
30	4.25	4.302
50	3.52	3.485
60	3.34	3.281
70 (current)	3.21	3.135
80	3.11	3.025

Table 15: Reverse logistics modifications

Key Insights

Cost analysis

This analysis provides insight into how the most important parameters influence each other in the system. It shows the effect of the kickback system and the return rate on the netto result.

- The current kickback system contributes negatively to the optimal return rate.
- A higher return rate does not necessarily mean a higher netto result as more costs are made for reverse logistics and cleaning.
- Keeping the flowtime as low as possible is crucial to make the system work.
- Keeping the cost price as low as possible is crucial to make the system work.

3.10 Fast track Lifecycle Analysis

A fast track life cycle analysis has been performed to compare the reusable Boks concept to a single use cardboard with insulation liner. It was found that BOKS contributes to less CO2 equivalent emissions after being used for at least 14.0 times. With an estimated lifetime of 100, this means that the BOKS has the potential to emit 68.32% less per trip. In this section these calculations and important assumptions and concerns for improvement are elaborated.

The tool

This analysis is executed with the Fast Track LCA tool for Reusable packaging from Kennis Instituut Duurzaam Verpakken (KIDV). The fast track LCA tool allows to compare reusable concepts to their single use alternatives. The comparison calculates the CO2 emissions over the complete lifetime and the costs of operations. The tool makes use of different sources, of which EcoInvent is the main source for material data. Additional material data has been added manually making use of CES EduPack provided by the TU Delft.

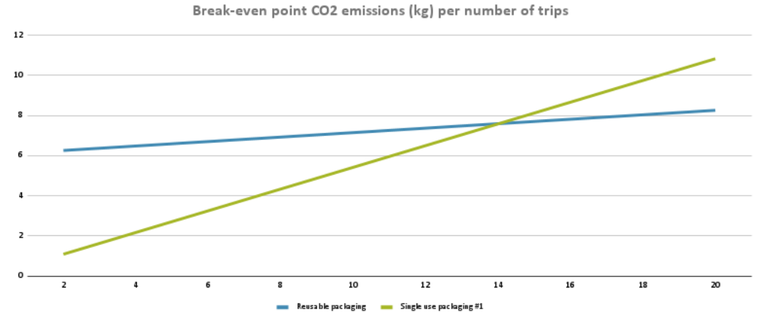
The scenarios described in table 16 were compared. Since this is a relative analysis, transport has been kept similar between these two scenarios. Data is based on the parametric model, solidworks model and cardboard boxes and insulation used by Goodcase:

	BOKS	Cardboard box
Volume	24 L	24 L
Weight	2015 g	500 g
Materials	PP (40% recycled content) + Hemp Fiber	Cardboard + Unbleached paper insulation
Cycles	100*	1
Costprice	€15.00**	€1.20

Table 16: BOKS compared to cardboard box
**Cycles are based on the general lifetime of a beer crate which is 10-20 years (Business Logistics, 2018). Given a cycle lasts 2 months this results in 60-120 cycles per crate.*
***Estimation*

CO2 emissions

For these scenarios, the CO2 emissions have been calculated keeping in mind sourcing, production, usage and end of life. This leads to a breakeven point after 14 trips, see figure 52. From trip 15 onwards BOKS will emit less CO2 compared to a regular cardboard box with insulation liner. Over the complete lifetime of 100 cycles this means that BOKS will emit a total of 17 kg of CO2 whereas using 100 individual cardboard boxes will emit a total of 54 kg CO2. This is a saving of CO2 emissions of 68.32% per trip.



Costs

Both scenarios show comparable development of costs as visible in figure 53. The break even point lies at 18.3 trips. From that trip onwards, BOKS will be cheaper. The main reason for this is the fact that BOKS does not need to be remanufactured over and over again. However, the difference is marginal. The costs are further elaborated in the cost analysis in chapter 3.9.

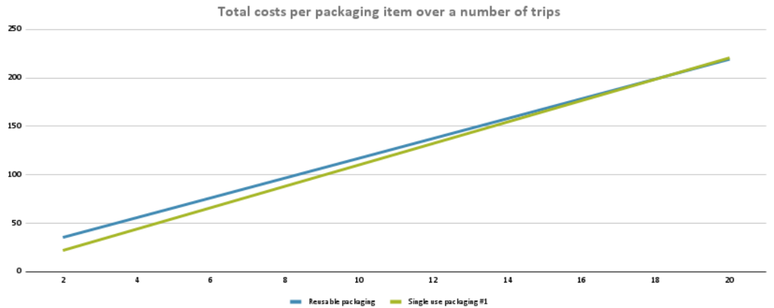


Figure 52: Break even CO2
Figure 53: Break even costs

Improvements and considerations

1. Decrease the weight

The weight of the box is a factor 4 times higher compared to the cardboard box. In the current state it is over-dimensioned with a wall thickness of 4 mm. Decreasing the wall thickness will affect the stiffness and strength of the box. However, this effect can be minimized by adding ribs on the inside and the outside of the box. The effect of wall thickness adjustments on the CO2 emissions can be found in table 17. This shows that designing the box lean is an effective parameter to decrease the environmental impact of the box.

Wall Thicknes [mm]	Break even CO2 [trips]	CO2 savings [%]
4 (current)	14.0	68.32
3	10.0	75.64
2	6.3	82.97
1.5	4.7	86.63

Table 17: Weight modifications

2. Cleaning method

The cleaning method has a drastic effect on the CO2 emissions. Industrial grade washing installations are considerably more efficient and less impactful compared to handwashing methods. Therefore, the system is modelled around these efficient cleaning methods. Although this might be not applicable from the start, it does show the potential of the system.

Cleaning method	CO2 emissions [kg]	Break even CO2 [trips]	CO2 savings [%]
Industrial (NaOH) (current)	0.01	14.0	68.32
Consumer grade washing	0.03	15.8	59.42
Handwashing	0.10	24.8	33.76

Table 18: Cleaning method modifications

3. Return rate

The current system is modelled around a return rate of 80%. A higher return rate leads to lower emissions and lower costs as described in table 19. The data output of the system describes that this effect is less impactful as the other parameters. However, the highest return rate should be pursued as it does affect logistics and the overall cost price of the product. Further impact of the return rate on the costs is described in chapter 3.9.

Return rate [%]	Break even CO2 [trips]	Break even costs [trips]
60	15.3	19.7
70	14.6	19.0
80 (current)	14.0	18.3
90	13.4	17.6
100	12.8	17.1

Table 19: Return rate modifications

4. Recycled contents

The current BOKS is modelled with 40% recycled content, as described in chapter 3.6. Percentages exceeding 50% usually show suboptimal properties (Thomas, 2020). A higher percentage decreases the CO2 emissions. The optimal amount of recycled contents with best fitting properties needs to be found while keeping weight reduction in mind.

Recycled content [%]	Break even CO2 [trips]
20	14.8
30	14.4
40 (current)	14.0
50	13.6

Table 20: Recycled content modifications

5. Cost price

As stated before, the current cost price is an estimation. The cost price might be considered a smaller factor in the operational cost as the number of cycles is higher. However, the data output of the model shows that this is an important parameter that needs to be considered. Keeping the cost price lower makes this model financially more interesting. Further impact of the cost price on the costs is described in chapter 3.9.

Cost price [€]	Break even costs [trips]
5	6.2
10	12.2
15	18.3
20	24.3
25	30.4

Table 21: Costprice modifications

Key Insights

Fast track LCA

- BOKS circulating in the current system shows potential to be 68.32% moreCO2 efficient compared to cardboard boxes.
- After 14 trips, the break even point is reached.
- BOKS circulating in the current system shows potential to be less expensive after 18.3 trips compared to cardboard boxes.
- Weight reduction is the most effective parameter to decrease CO2 emissions.
- Industrial grade cleaning is drastically more efficient compared to handwashing.
- A higher return rate decreases environmental impact and costs.
- A higher percentage of recycled contents decreases the CO2 emissions.
- Lowering the cost price is an effective parameter to lower the break even point for cost.

3.11 Process

In this chapter the process during the ideation phase in this graduation project is described. The main process in the analysis phase is described in chapter 3.1.
Overall the process is a combination of diverging and converging. An overview of the process can be found below.

Process steps discussed in this chapter

1. Direction (morphological chart)
2. Ideation session (with Goodcase customers)
3. 3 concepts
4. Concept selection 1 (weighted criteria)
5. Testing (insulation and costs)
6. Concept selection 2 (weighted criteria)
7. Design challenges update (program of requirements)
8. Development
9. CAD
10. Testing
11. Prototyping
12. User testing

1. Direction

From the midterm presentation described in appendix O , three directions have been developed based on the morphological chart in figure 54.
The soluble starch based concept has been removed from the list. First of all, it is a single use solution whereas the analysis shows that reusable solutions are in fact more sustainable. Second, a lot of energy is put in the development of the material which is subsequently lost by dissolving in the water. Not being able to (partially) recover the resources does not fit in a circular paradigm. As a result fibers are also included as a potential direction.

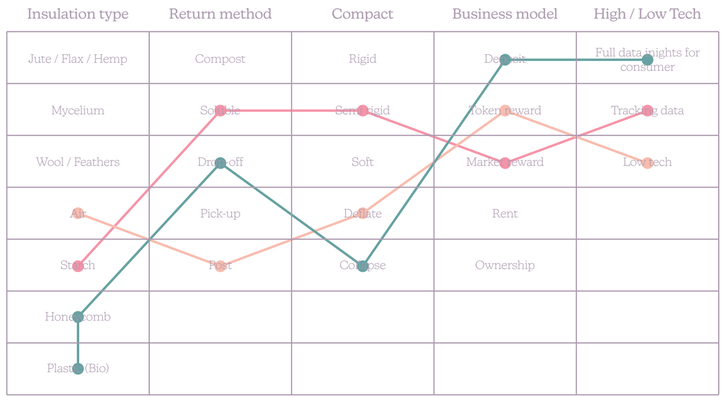


Figure 54: Morphological chart for direction

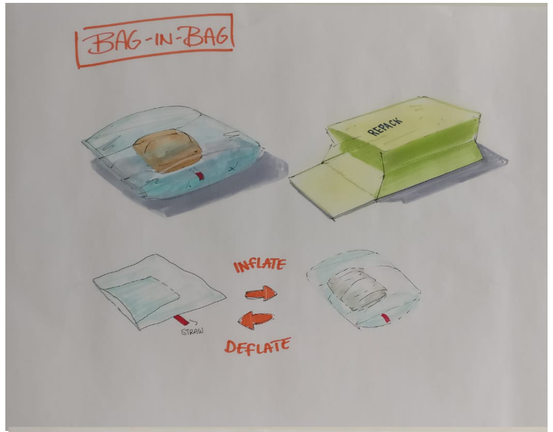
2. Customer ideation session

With that in mind a digital ideation session has been executed with actual Goodcase customers, the findings can be found in appendix P. In this session potential solutions have been discussed and insights in the customers' perception towards reusable packaging has been gathered, see figure 55. It was found that the customer group is willing to make an extra effort to drop off the reusable packaging, however they want to stay in control when and how they return their packaging.

Figure 55: Outcome of creative session with Goodcase customers

3. Concept development

Three concepts have developed based on these directions.



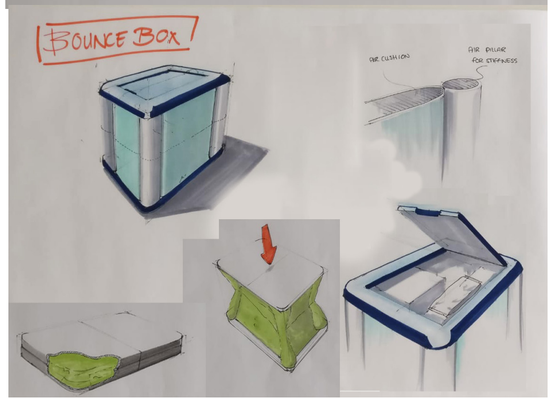


Figure 56: BAG in BAG concept
Figure 57: Bouncebox concept

BAG in BAG

This concept makes use of enclosed air pockets that act as insulators, see figure 56. The product is placed in the inner bag. The outer bag is subsequently inflated making use of the red inlet on the side of the envelope. By inflating, the products get locked in the middle of the air cushion, which acts as a thermal insulator and shock shock damper. This concept fits perfectly with systems that are already in place such as RePack.

Once the package arrives at the customer, they can easily deflate the cushion by inserting a straw into the red tube. As air flows out of the cushion the products can be taken out. To send the package back to Goodcase, simply put the insulation back into the RePack bag, fold it and drop it off at your nearby mailbox.

Bouncebox

This concept is inflatable making use of a compressor of bicycle pump. Inflating will transform the flat box (bottom left) into the expanded box (top). The edge columns give the structure stiffness. The side cushions can be inflated afterwards to increase insulative performance. Products can be inserted via the lid on the top, see figure 57.

The customer can take the products out of the box and deflate it into a flat state. This compact box can subsequently be dropped off at a local drop off point.

Fiberbox

This concept has an insulative layer made of plant based fibers, see figure 58. The box is foldable as demonstrated in the drawing. The blue hinges make it easy to fold while remaining robust at the same time. Products can be inserted via the panel on the side.

The customer can take the products out of the box and fold it into the flat state. This compact box can subsequently be dropped off at a local drop off point.

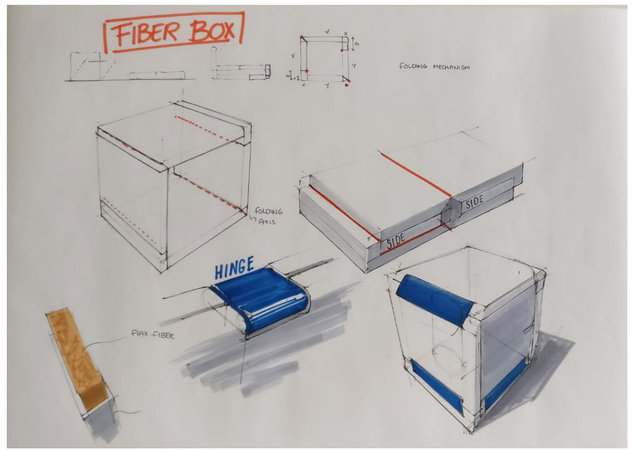


Figure 58: Fiberbox concept

4. Concept selection 1

The performance of these concepts was subsequently compared based on these criteria. This set of criteria is prioritized based on their importance.

- **Performance (5)**
  The solution shows potential to keep products cooled efficiently within the required timeframe.
  From the logistics and thermodynamics analysis (chapter 3.2 and 3.8 respectively) it has been concluded that the products should stay below 5 degrees celsius for at least 36 hours to guarantee a successful delivery.

- **Cost (4)**
  The solution shows potential to keep costs to keep products flowing as low as possible.
  From the cost analysis (chapter 3.9) it has been concluded that the reverse logistics are a major part of the cost per cycle. In order to decrease these costs it becomes increasingly important to reduce the size and weight on this trip from the consumer to Goodcase Packaging.

- **Reuse (3)**
  The solution shows potential to keep itself in the loop for as long as possible.
  Increasing the number of cycles is more sustainable as less waste will be created and less remanufacturing is required. On top of that it decreases the overall material cost per cycle.

- **Sustainable (2)**
  The solution shows potential to keep the environmental impact minimal compared to current solutions.
  This mainly focuses on the impact of the materials and the emissions to keep the product flowing. Minimizing these two creates has the potential to create a lower impact compared to current alternatives.

- **Goodcase (1)**
  The solution is innovative, has the potential to become an asset for Goodcase and fits with the use case (shipping food and logistic process).
  The solution has the potential to be implemented in the described system on a larger scale and become a revenue stream for Goodcase Packaging.

Applying these criteria to each concept led to different scores based on their performance and the weight of the criteria, see figure 59. This has led to the following scores, whereas the left one displays the unweighted scores and the right one displays the weighted scores.

The exact scores and elaboration can be found in appendix H.

From this analysis the Bouncebox clearly did not meet the criteria with an overall score of 36. The overall performance of the Bag in bag (53) concept and the Fiber box (49) was concluded to be comparable, although they clearly excel in different areas.

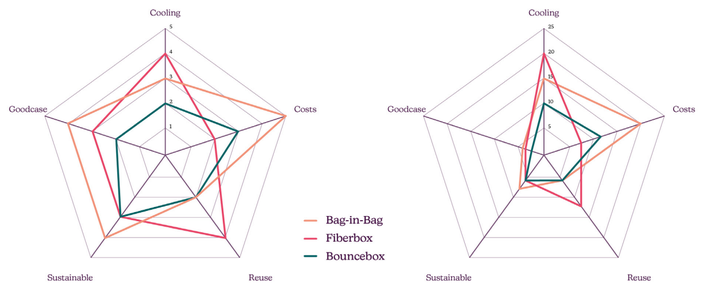


Figure 59: Spider web weighted criteria

Insight gained:

The weighted criteria method works great to compare different concepts relatively. However, its accuracy is limited since so many assumptions are involved in the assessment. Therefore, further validation is required in order to be able to make a ground decision. It is decided to further test the two most important criteria since both concepts show substantial differences for those criteria.

5. Testing

Insulation

Two iterations of testing have been executed under comparable conditions. The complete testing reports of iteration 1 and iteration 2 can be found in appendix C.

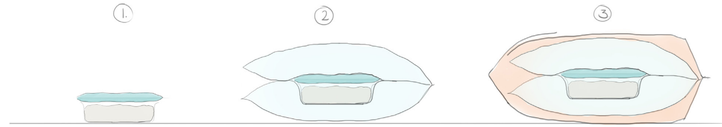


Figure 60: Testing setup iteration 1

Iteration 1

The goal of iteration 1 was to identify the insulative effect of both an enclosed air layer and a protective outer layer. Three tests were conducted simultaneously, see figure 60.

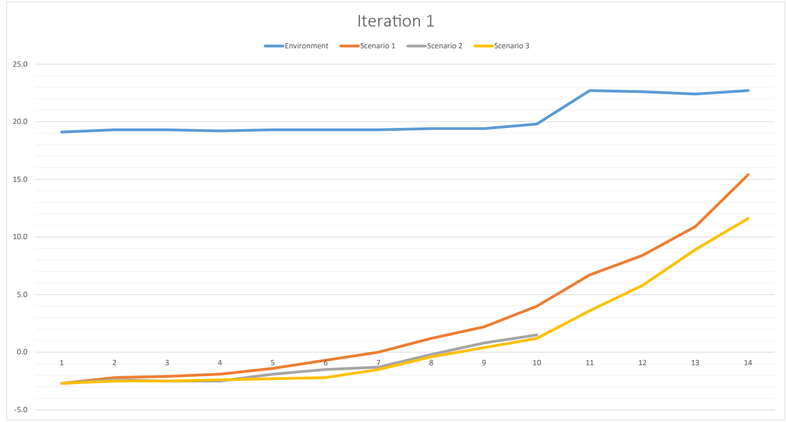


Figure 61: Results iteration 1

Conclusion iteration 1

This research provides insights into the insulative performance of an enclosed air layer. The effects of different layers can be assessed, see figure 61. The measured data shows a distinction between scenario 1 (without insulation) and scenario 2 (BUBL Bag). The described trajectory of scenario 2 shows a less steep incline in temperature. However, this difference is minimal. Scenario 1 reaches 5 degrees Celsius after 10.5 hours whereas scenario 2 reaches this temperature after almost 12 hours. This suggests the influence of the enclosed air layer is apparent, however it is considered minimal. Adding an extra outer layer also adds little insulation. Further testing with the multiple chamber insulation is required to optimize the performance of the insulative layer.

Iteration 2

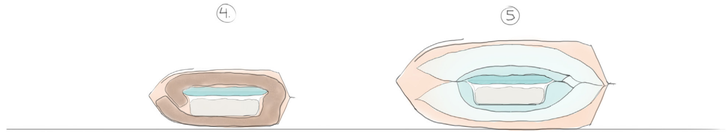
The goal of this research is to get a better understanding of the insulative performance of the improved bag-in-bag concept with multiple chambers and the concept with fiber insulation, see figure 62.

Conclusion iteration 2

The double enclosed air layer in scenario 5 shows a minor improvement in insulative performance (14 Hr) compared to the single bag test performed in iteration 1 (12 Hr). Extrapolating this line would suggest that adding more chambers will increase the insulative performance. This is in line with other insulators like EPS, which consists of a large amount of small enclosed air pockets.
The fibers in scenario 4 act as an excellent insulator (34 Hr), compared to scenario 1 (10.5 Hr), see figure 63. Due to its structure it creates a large amount of air pockets which decreases the heat flow in the material.

Conclusion and advise

The fiber insulation performs substantially better than an (multi chamber) enclosed air insulation layer which is clearly visible in the figure below. Therefore it is advised to continue with fibers as an insulation material.



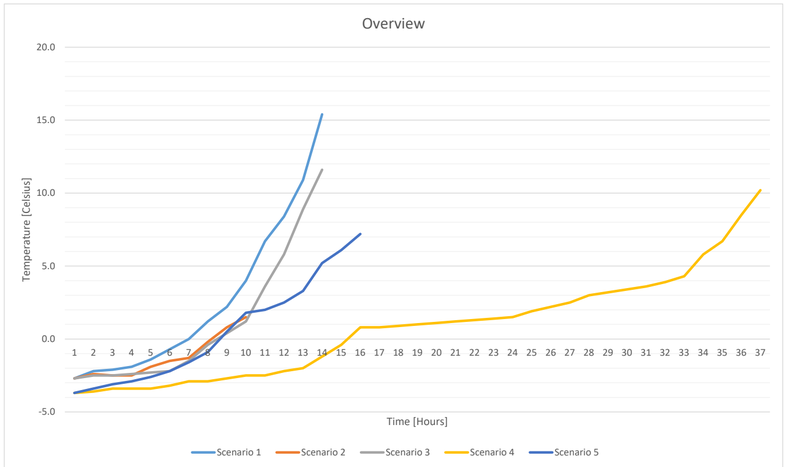


Figure 62: Testing setup iteration 2
Figure 63: Results iteration 1 and 2

Costs

This analysis focuses on the difference between a mailbox sized return and a regular parcel return. Due to the competitive nature of the logistics market, the prices are comparable.

Table 22: Cost comparison

	Mailbox [€]	Parcel [€]	Percentage difference [%]
PostNL	4.10	6.25	35
Fietskoeriers	4.65	6.44	28

Due to lack of a proper reverse logistics infrastructure these packages usually get classified as regular parcels, see table 22. Setting up a proper structure on a significant scale could have the potential to drop the prices of reverse logistics. Fietskoeriers is currently working on setting up a reverse logistics network. In email correspondence they suggest a price of €3-4 for mailbox and €4-5 for a regular parcel.

Setting up a system with local hubs that collect the empty boxes which are subsequently shipped in bulk has the potential to decrease the price even further. Nevertheless, the size and weight need to be minimized to keep the costs as low as possible.

Conclusion and advise

There is a price difference in the range of 25 - 35% between mailbox and regular parcels. This could lead up to €2 difference which is substantial in the CEP market with thin margins. Rolling out a potential system with hubs on a larger scale could help in decreasing the price further. Although this is expected to have little effect on the percentage difference, it could have an effect on the price difference in the end.

It is advised to go for a mailbox sized parcel. If this is not possible, efforts need to be put in making the parcel compact and lightweight as this allows for efficient shipping. Besides that, it is advised to crystallize the logistic system further with partnering companies.

6. Concept selection 2

Based on the further testing the weighted criteria method is revised leading to the following results, see figure 64. The Bag-in-Bag lowers on the coolin performance, whereas the fiberbox scores higher. Concerning the costs, the relative difference is considered to be lower as estimated before. As a result the fiberbox scores a little better, but the Bag-in-Bag is still performing better on this criteria.

This leads to the following overall score: Fiber box (58) Bag-in-Bag (48). With these scores, the fiber box is the chosen concept to continue with.

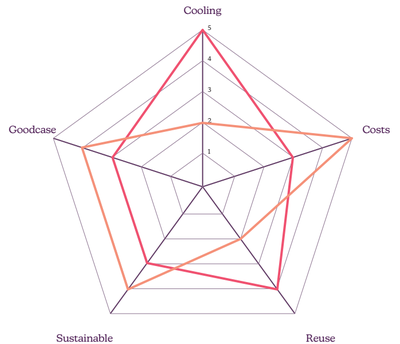
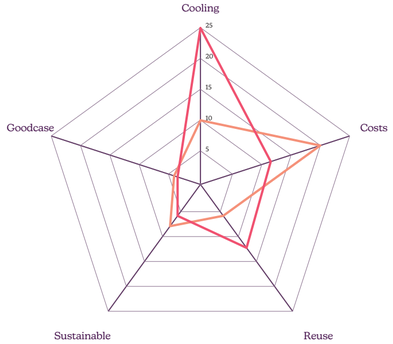


Figure 64: Spider web diagram visualizing the scores unweighted (left) and weighted (right).



7. Design challenges updated

The design challenges are refined according to the chosen concept.

Performance
Optimize the passive cooling to keep perishable goods reliably within the right temperature range during transport up to the point where it arrives at the customer. Functioning is guaranteed all year around, including hot summer days.

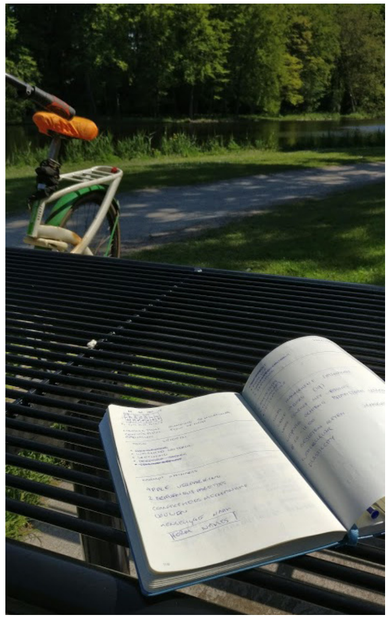
Reuse
Create a reusable solution with a viable business model which creates incentive for all stakeholders to keep the product flowing. To set up the system, collaboration with other parties like logistics, maintenance and service providers needs to be explored.

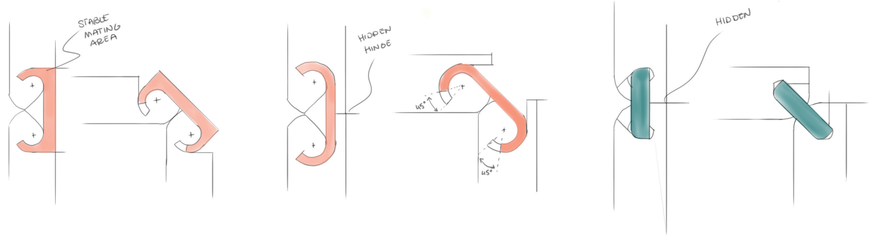
Sustainable
Minimize environmental impact over the whole lifecycle of the product. Educate and inspire consumers about the environmental impact of packaging through materials, data and stories.

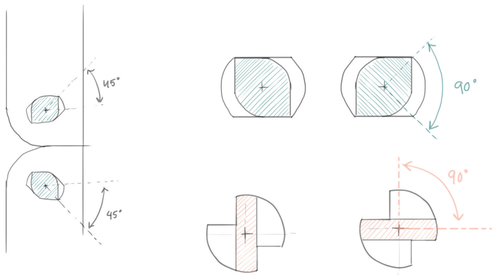
Goodcase
Optimize the solution to become an asset for Goodcase Packaging. The product should focus on inspiring consumers with a high quality experience. Simultaneously, the solution should be easily adaptable to other companies while keeping the cost for usage low.

8. Development

In this phase the folding mechanism is analyzed by building lo-fi prototypes. Additional sketching and ideation is done while enjoying the weather in the park!







The hinges have been tested using sketchin, CAD and lo-fi prototyping combined, see figure 66 and 67. This allowed me to get a better understanding of the movement and the intended behaviour of the folding mechanism.

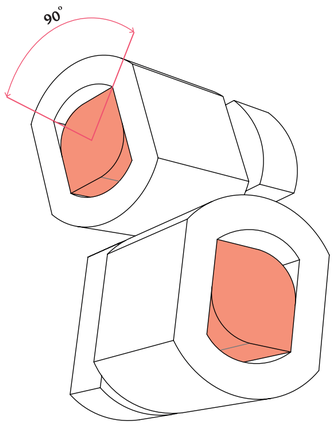
Figure 65: Workign in the park
Figure 66: Hinge design sketching
Figure 67: Folding structures lo-fi prototypes

9. CAD

The design has subsequently been generated in CAD, see figure 68. Additional problems with interfering parts have been solved to optimize the folding mechanism. The design is made by closely watching the modularity. Reducing the amount of parts and making the hinge universal.

10. Testing hinge

The two hinge types were tested using 3D printing. This analysis showed that the concept with the square with fillets outperformed the bar concept. The chosen concept has a lower friction since there is less contact area, see figure 69.



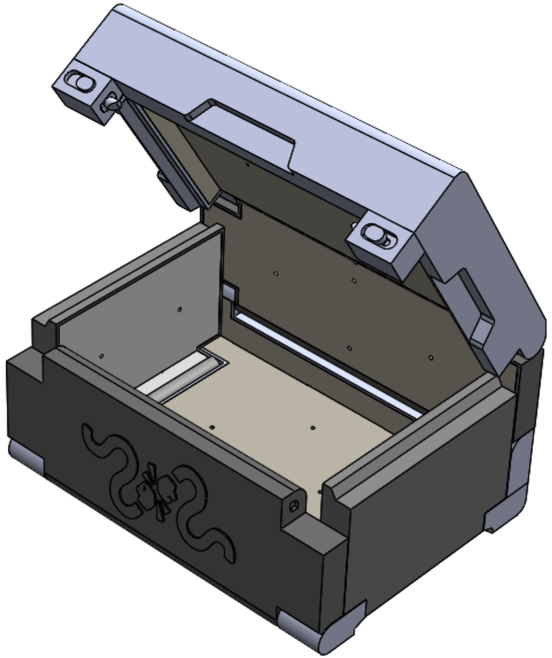
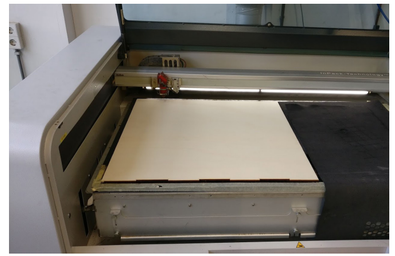
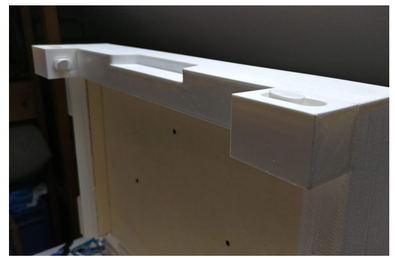


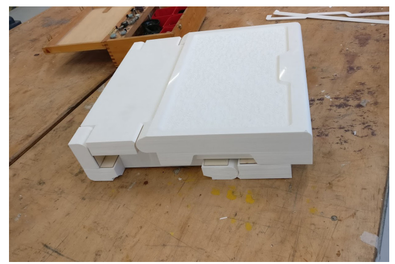
Figure 68: CAD model
Figure 69: Hinge design
Figure 70: Collage of prototyping process

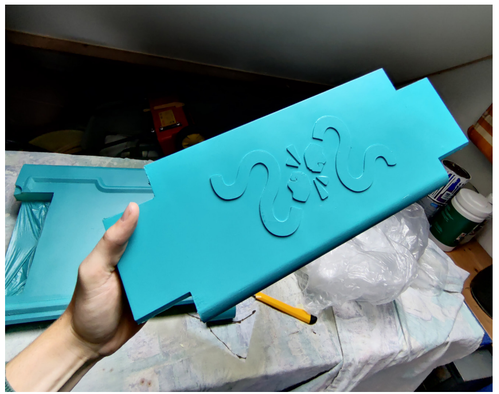
11. Prototyping

The prototype is made using 3D printing and lasercutting. An impression of the process is displayed in figure 70:









12. Performance testing

The goal of this research is to get a better understanding of the insulative performance of BOKS compared to the parametric model. More specifically, how well does the model represent real world data? In order to do so, a test is designed to measure the insulative performance of BOKS, see figure 71.

Conclusion performance testing

From the test data it can be concluded that BOKS is capable of keeping the selected products under 5 degrees for at least 32 to 38 hours depending on the type of product, see figure 72. Compared to the hypothesis of 24 hours this is quite a big difference. The parametric model does not calculate extremely realistic results as expected given the drastic simplifications made.

In addition, the path of the line in the parametric model is fluent almost like a root function. Whereas the path of the measured data resembles the shape of a phase change diagram. To make the parametric model resemble real world data more, various improvements are suggested and described in chapter 3.8.

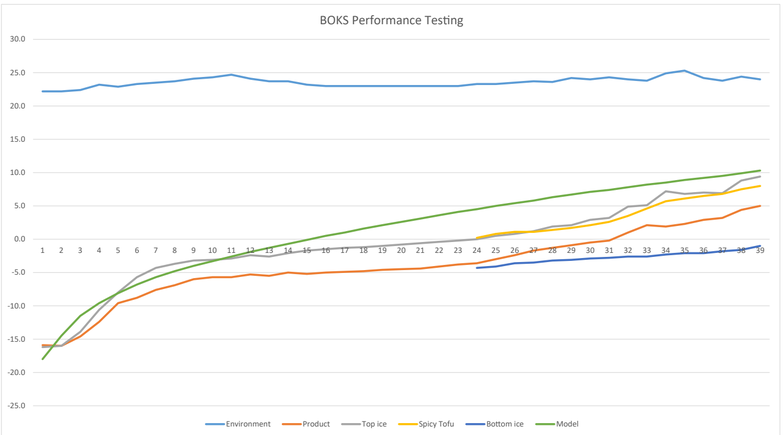


Figure 71: Test setup
Figure 72: Results performance testing

13. User testing

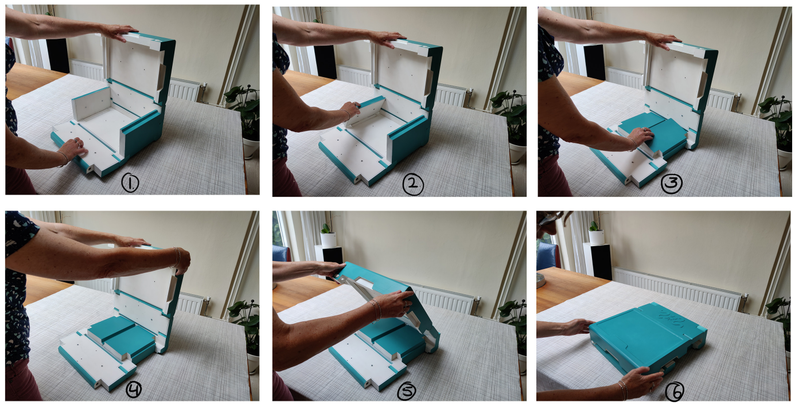
User test with 6 participants has been performed to analyse the interaction with BOKS. The task was given to open BOKS, take the products out and fold BOKS.

While opening, it was clear that the buttons needed to slide outwards. From step 2 to 3 participants started to switch hands and grab the top part at the handle. The interesting part here is that the lid first needs to be lifted (1 to 2) to unlock it. This is counterintuitive as participants expected that once the button was slid outwards it would remain 'unlocked'. Having the handle in the front is confusing if it is not necessary to unlock it. Therefore it is concluded that the locking mechanism needs to remain unlocked once slid outwards. Another option is removing the handle, however, this feature is proven to be functional to lift the lid and unlock it from the folded state.

While folding, one hand is occupied to prevent the lid from collapsing. As a result the whole folding procedure is performed with one hand, which is sub-optimal. Locking the lid once it is in a vertical state would enhance the overall experience of BOKS. Furthermore, all hinges are designed to fold in one direction, however, this is not indicated in the design. Adding signifiers with folding instructions would speed up this action and prevent malfunction. For the rest the folding procedure is perceived as straightforward. Closing BOKS is a different story. It is unclear if the buttons are locking since it is at an awkward angle for the user. Therefore, they thought that it was locked while it was not. This could cause malfunction. In addition, the prototype has a little play which could cause misalignment as can be seen in figure 75.

In addition, the pins of the folding closing are not chamfered properly. If the user wants to close BOKS, it needs to slide the buttons outwards. It would enhance the experience if this happens automatically.

Figure 73: Opening user test
Figure 74: Folding user test
Figure 75: Misalignment



Reflection

Graduating in your own startup

From the start of this project I felt excited to graduate within my own startup. The BYS elective awakened my entrepreneurial spirit which sparked my motivation to continue with Goodcase.

This past half year taught me that motivation will drop fast once you stop believing in what you are doing. From the start we worked out a plan on how to gather new insights for Goodcase while combining it with our graduation projects. During the course of the project we started selling our new snack box. Selling the box took too much energy and attention, since all three of us had no experience selling products. It costs us more effort than we could afford during that phase of the graduation which resulted in low sales and expectations not being met.

This in combination with a.o. struggles within the team, caused me to slowly stop believing in Goodcase. Over a month this was stuck in my head which drained a lot of energy and caused me to be less productive on the graduation project. Once the decision was made and discussed with the team and Matthijs it actually gave me a feeling of freedom and an energy boost to finish the graduation project.

Looking back, I am still happy that I combined graduation with my own startup. As it gave me experiences and insights that will be valuable for my future as a designer and entrepreneur. The overall lesson here is if you want to do something outside of your comfort zone it requires attention, effort and perseverance. We expected good results straight away, whereas it might take a hundred more tries before it works out well. Normally I don't quit fast, but since we did not have the time/energy to focus on selling the box, it became harder to believe in the team and the cause of Goodcase. The effect of stopping believing had a drastic effect on my motivation, which eventually led to killing it.

For future students who want to combine their startup with a graduation project, I definitely would advise to discuss the expectations upfront and continuously reflect during the process. Otherwise it might end up like Goodcase.

Relation with supervisory team

From the start I urged the supervisory team to challenge me with critical questions. During this project I learned that this attitude challenged me to look at the problem from different perspectives. During the process you can find yourself so deep in the field as you are trying to make sense of the complexity. However, this elaborate understanding can also be limiting your overview, flexibility and creativity. Each supervisor brings their own knowledge and experience and this diversity gives them the power to open your eyes by asking the right questions.

In the beginning of the project I had to make a decision to continue with a single use or reusable solution. From the BYS elective I learned that it was important to make a decision and keep on moving instead of trying to analyze everything before you reach a decision. With the knowledge at that time, I chose a single use solution. Matthijs realized that my argumentation had some flaws and underexposed areas. By simply asking the question if I thought that this really was the best way to go, he triggered my doubt in the decision. He advised me to revise the decision, which changed the course of this whole project.

Approach with fundamentals

During the master course AED I developed the fundamentals and challenges method. This method allows the designer to make intangible characteristics of the context concrete early on in the process. In that project this method worked so great that I wanted to apply it to this project too. During the course of this project I needed to tweak it quite a lot to make it fit with the context, that process is described in appendix A.

Applying this self developed method resulted in fruitful discussions with the supervisory team. I needed to convince them of its uniqueness and added value. Since I was also still searching for the optimal application and description, it was difficult to convince them. Though I felt energized by the discussions and critical questions from the supervisors. That helped me to continuously rethink the core value of the method. In addition, after two projects it became apparent that this method works differently based on the kind of project. It requires additional research to make it more universal and better fitting with various kinds of projects.

Final Result

Doing a graduation project feels like showing one last time what you are capable of. From the beginning I was determined to create a physical solution I would be genuinely proud of. Looking back at the final result I feel proud of the design, the prototype and the report. The overall quality and performance represents my capabilities as a design engineer. The handson and structured process where I got the chance to speak with many inspiring experts shows my entrepreneurial capabilities.

Looking back at this project you almost forget how little you know at the start of the project. Within a short time I dove into the field of circular economy, thermodynamics, logistics, food and packaging. Now you realize how much you learn in such a short time. This became apparent when I was part of a brainstorm of a new startup working on reusable packaging for ecommerce. During that brainstorm I was able to answer almost all their questions. At such moments you realize how deep your knowledge is.

On the other hand it also becomes clear how much there still is to learn. The graduation project might be finished, but BOKS is far from finished!

My take on BOKS from an entrepreneurial perspective

I believe that reusable ecommerce packaging will definitely become present in the future. The initial market will play a crucial role in the switch to reusables. For example the fashion market is characterized by a high return rate. This would be an ideal beach head market for reusable packaging as the whole process can be redesigned to enhance the customer experience.

In my opinion the current market of BOKS is not optimal to start in, as it is characterized by a large quantity of smaller companies and therefore lower quantities. Scale plays an important role to the feasibility of BOKS as became clear from the financial model. The subscription mealbox-market would be much better as a beachhead market. Recurring deliveries take away the need for a complicated reverse process, moreover they increase the returnrate. All BOKSES can be recollected, cleaned and maintained in-house, which simplifies this process compared to external recollecting. In addition this does not require Goodcase packaging to set up a return system which is a costly business, instead Goodcase packaging can sell BOKS to for example Marley Spoon or Hellofresh.

The design itself needs to be optimized for that purpose as well, since you are dealing with a different logistic journey. In addition, the design is overdimensioned and can be designed much more lean.

Conclusion: I believe in the cause of BOKS. I am convinced it has the potential to add value to the subscription mealbox market. I am willing to offer BOKS to Marley Spoon, Hellofresh or other subscription mealbox companies. I would only do so, if I can be part of the optimization iterations to make it fit in the context.

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Red je Pakketje: Mieke Steenbrink (Customer Success Manager), Rein Hofhuis (Sales & Capacity Manager)
Returnless: Marijn Prijs (CEO)
Budbee: Jonathan Maduro (Sales)
Suppliers: Shen Liu (YEX), Sander Peltenburg (Krekerij), Marco Koemans (Botanic Bites), Florian Rath (BUMI), Gertjan (Upside), Wouter Swolfs (Firma Kaas), Mike Maduro (Freggies)
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Appendices

List of supporting researches, tests and interviews

Appendix A

Evaluation of Design Fundamentals and Design Challenges

Appendix A: Evaluation of Fundamentals and Challenges

Design Fundamentals

Make sure the product fits in the context

In order to make the product fit in the context it needs to comply with the rules of a circular system. The vastness of research performed makes it easy to overlook all separate findings during this project. In order to prevent insights from being missed during the design phase, most important insights have been written in concrete actionable points. All findings with a direct and indirect (foreseeable) influence on the design have been synthesized into these design principles. Besides the program of requirements, see chapter 2.8, they are used as a set of context based requirements that all design challenges should meet. If the principle is met, it can be concluded that the design fits in the context. The design fundamentals are presented on the next page.

Design Challenges

Make sure the product functions as intended

Identifying the challenges has been the result of the analysis performed prior to the midterm. During the design phase these have been continuously improved. The design phase puts emphasis on solving these challenges and integrating them into the design. Each challenge has its own set of requirements. The challenges describe both the tangible properties of the product and the (in)tangible characteristics of the system.

In this section the pros and cons of this method are discussed:

Pros

- It forces the designer to synthesize and prioritize the findings from the analysis. These concrete conclusions from the analysis phase is the basis for high quality input in the design phase.
- It clearly distinguishes the context requirements from the product requirements, which provides structure to the process.
- It helps dealing with complex and multilayered contexts.
- It helps in communication to external clients and stakeholders as ideas are clearly backtrackable.

Con’s

- Fundamentals are time dependent, although the term fundamental suggests a set in stone principle that is not time-independent. The name might be misleading to the actual functionality of the tool.
- Extensive time, understanding and preparation is required to create the fundamentals early on in the process. This time is won at a later stage in the process.

Evaluation in this project

This is the second project where this method is used. Compared to the first project some tweaking was required to make the approach fit with this project. Whereas the first project was BOP (bottom of pyramid) and therefore described unrelated cultures. The tool was mainly beneficial to capture intangible culture fundamentals that need to be subtly present in the design. For that project the fundamentals were mainly focused on the habits of the user.

For this project, it was not specifically a culture related application of the tool. This project focuses on the paradigm of the circular economy. Therefore the fundamentals are tweaked towards describing the intangible characteristics of such a system. This suggests that the fundamentals could in fact describe part of the context, while it does not exactly describe the habits of the user. As a result the user might be under-present in the process.

Without a doubt, there is potential for this method to guide the designer for any IPD-type project. The structure it provides smoothen the process and make external communication easier. However looking back at these two projects, I would say that the fundamentals were more effective for culture related challenges in the first project. The user focus generated additional value based on insights that otherwise might have been neglected. For this project the fundamentals were useful because of the schematic, which clearly displayed what buttons to turn for a positive outcome.

Appendix B

Correspondence and interviews with suppliers and webshops

!?

Interviews Suppliers

Interview Questions

Name	Date	Question 1	Question 2	Question 3	Question 4	Question 5	Question 6	Question 8	
Untitled		**Vervoer je gekoelde producten? Zo ja, hoe doe je dat? - Logistieke partner - Materialen - Welke temperatuur?**	**Hoe ben je bij die oplossing gekomen? Waarom werkt die voor jou het beste? Welke andere opties heb je overwogen?**	**Hoe werkt de huidige oplossing? Wat zou er verbeterd kunnen worden? Waar loop je tegenaan?**	**In hoeverre speelt duurzaamheid een rol bij de huidige oplossing?**	**Wat vinden je klanten van de huidige oplossing?**	**Wat zou jouw voorkeur hebben: een oplossing die herbruikbaar is of een oplossing voor eenmalig gebruik?**	**Waarop zou mijn concept ondersheidend moeten zijn voor jou om het te kopen.**	**Heb of mer waa mee nem**
Freggies	@March 16, 2021	papieren wrap en koelblokken. Blijft diepvries en 24u gevroren. zelf getest tot 16-18 uur. Trunkrs. Redjepakketje, slechte service. 4 vd 8 pakketten kwamen niet aan of te laat of niet geretourneerd.	voor webshop was dit de beste oplossing. prijs speelt hoge rol.	bijvoorbeeld 48 uur. veel minder druk. druk ligt meer bij vervoerder. 11.00 afleveren pakketten vlak vooraf gemaakt. halve dag vooraf al inpakken.	materialen, gerecycled milieuvriendelijk en herbruikbaar.	oogt goed, geen plastic. koelblok	verschillende adressen met retoursysteem uitdaging. omdat vervoerder neit kan duurzaamste single use verpakking.	kwaliteit gemak uitstraling capaciteit gewicht. even zwaar als huidge oplossing. zwaarder dan beter isolerend. volume is belangrijk, nu ongeveer €6 per doos kwijt. makkelijk retour of herbruikbaar is, klein beetje meer betalen.	
Wouter Swolfs (Firma Kaas)	@March 10, 2021	worden niet gekoeld geleverd. kaas retail gaat wel koeltransport. kaas normaal rond in pakhuis normale temperatuur. **Kaas buiten koeling: vacumeren tot 25 graden tot 3 dagen. PostNL last mile.**						kartonnen doos met koelcapaciteit. **Postnl is een kartonnen koeldoos aan het ontwerpen.** Omdoos. dubbele laag met koeling capaciteit. b**rievenbusdoosjes met isolatie materiaal is koeling niet interessant qua dikte.**	Vlee LaC cut

Name	Date	Question 1	Question 2	Question 3	Question 4	Question 5	Question 6	Question 8	
Upside (Brandplant)	@March 3, 2021	leveren vanuit fabriek naar klant. grote orders. supermarkten etc. Meest efficiente manier. Gekoeld gebundeld tranpsort. PostNL Food leveren aan winkels. voorraad staat bij hun. Niet DTC levering. Pianta Pasta komt nu in zakken via de post.	Nog te duur. minimale order voor consument boven de 25 euro. Plattere verpakking.	geen vertrouwen dat het echt werkt. Voeding regelgeving. voedsel en waren autoriteit. Gegarandeerd een product binnen bepaalde marges. **Max tot 14 graden.** Plantaardig dus iets minder gevoelig voor hogere temperaturen. Ziektekiemen die ontstaan gedurende bepaalde processen. **stuur ff reminder.** veiligheid staat voorop. bevroren opsturen gaat niet lukken, product verliest te veel kwaliteit. **bureau de wit**	speelt een rol. niet nummer 1. kwaliteit is belangrijk. stel doen door koelelement en alu folie dan zou ik het niet willen moet dan wel recyclebaar of composteerbaar zijn!		idealiter herbruikbaar. gebruiken nu al koelelementen die herbruikbaar. lastiger verhaal als voor B2C.	**bewijs dat het werkt** en dat het **door de brievenbu**s kan en prijs. €1.50 voor het versturen van 2 producten.	**Firn Wo**
Bumi	@March 2, 2021	geen DTC. alleen aan tussenpartijen. CNL logistiek voor opslag en transport. actieve koeling. Leveren voor horeca kleine zaken.	alleen samples niet actief gekoeld. duurzame koelbox met koelelementen. max houdbaarheid 2 dagen. ecokoelbox. BUNZL koelelementen van recycold.	veel aanbod transport kosten veel te hoog.					
Botanic Bites	@February 26, 2021	produceren zelf niks. jan zandbergen duurzaam vervoer. energieneutraal produceren. prijs doorslaggevend.	nee nog niet. Out of the box.		nog niet heel veel.	nee nog niet over gesproken. zou usp kunnen zijn.	milieubelasting	milieubelasting. mag best iets meer kosten. **opslag van 10 cent. niet euros meer per kilo.**	niet wer met vrie

Name	Date	Question 1	Question 2	Question 3	Question 4	Question 5	Question 6	Question 8	
Krekerij	@February 23, 2021	ja gekoeld in consument bevroren horeca. voor 00.00 tussen 12 - 13 afleveren tussen 17-22 geleverd heel nederland. verpakkingen vrij duur. eerset test alufolie test → recycold **€3 per verpakking +2 koelpacks.** verzendkosten €8. grote aantallen tot €5. bevroren in vriezen klaar. kartontape. alles recyclebaar.	hele lijst gemaakt met alternatieven. altijd boven de €5. en deze werkt. **Redjepakketje. vanavondbezorgd. trunkrs** is wat duurder. nog geen probleem ondervonden met consumenten neit thuis. Ff bellen of mailtje vooraf sturen (0% afkeer)	dat iemand het bij hem in komt pakken. volumes zijn nog laag. dus inhouse productie.	Duurzaamheid is wel een duidelijke factor. zo veel mogelijk karton en kartontape	goed. tekst op buitenkant met krijtstift en sticker met naam.	PostNL. kratten die heen en weer meot sturen. **Heel duur. Leveringszekerheid is laag. Veel moeite.** Rotterzwam neemt kratjes terug.	**lengte van koel blijven is cruciaal. bijvoorbeeld 3 dagen koel blijven.** Belgie is 2 dagen transport. Europa zou volgende stap. **snelheid vs kosten vs koeltijd**	duu verp bij v fabr
YEX	@February 17, 2021	Ja, vervoeren we zonder extra toevoegingen. Met **Trunkrs kunnen we same/next day delivery doen.**	Simpelste en goedkoopste oplossing. Maar vervoer is nog steeds duurder dit zouden we graag goedkoper willen doen. bijvoorbeeld met een reusable koeldoos	werkt prima, maar wel riskant. **als klant niet thuis is levert het al gauw problemen op.**	Een grote rol. We willen niet onnodig veel materiaal gebruiken. en het liefst materialen die recyclebaar of herbruibaar zijn	-	Een oplossing die herbruikbaar is, maar het logistieke model met het ophalen van de doos is wel een flinke uitdaging		Kijk isol pap
Untitled									
Untitled									
Untitled									

Appendix C

Testing of insulation performance

BUBL Bag testing

1. Research objective

The goal of this research is to get a better understanding of the insulative performance of the bag-in-bag concept. More specifically, how long this concept is capable of keeping the product under 5 degrees Celsius. In order to do so, a test is designed to discover the insulative effect of both the enclosed air cushion and the outer bag.

2. Research Question

2.1. What influence does an enclosed air layer have on the temperature trajectory of frozen food?

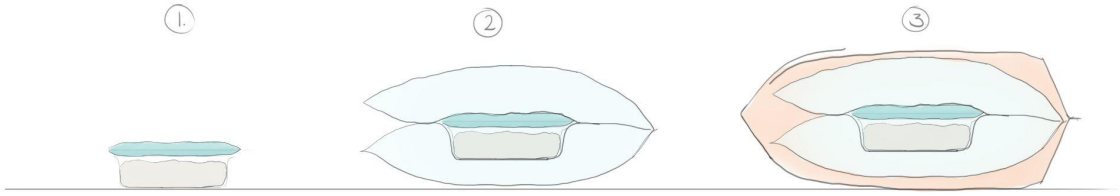
2.2. What influence does an extra outer layer have on the temperature trajectory of frozen food?

3. Method

3.1. Research Setup

In order to answer these question the following test is conducted with three different scenarios:

1. Product with cooling pack
2. Product with cooling pack in a bubl bag
3. Product with cooling pack in a bubl bag in a Repack



These three scenarios allow the measurement of the insulative performance of each layer distinctively. All tests are performed simultaneously to decrease the influence of environmental influences.

3.1.1. Apparatus

Frozen Spicy tofu chunks (200 g) (3x) - to act as the product that needs to be cooled
Ice packs (400 ml) (3x) - to act as a coolant inside the packaging
Bubl Bag (40 x 40 cm) (2x) - to simulate an enclosed air cushion
Repack - to simulate the outer bag
Infrared thermometer - To measure surface temperature

3.1.2. Procedure

The temperature of the product cannot be measured through the insulation layer. Therefore, the bag needs to be deflated before the product can be taken out for measurement. Due to this fact, the following procedure is chosen to interrupt the process as little as possible while generating enough data to form good conclusions.

The following temperatures are measured with an one-hour interval:

Environmental temperature

Scenario 1
- Ice temperature
- Product temperature

Scenario 2
- Outside temperature bubl bag

Scenario 3
- Outside temperature RePack

The following temperatures are measured with a three hour interval:

Scenario 1
- Ice temperature
- Product temperature

Scenario 2
- Outside temperature bubl bag
- Ice temperature
- Product temperature

Scenario 3
- Outside temperature RePack
- Outside temperature bubl bag
- Ice temperature
- Product temperature

3.1.3. Data collection

Data is collected with the thermometer following the described procedure. The temperature is measured at predefined locations on the objects. The data is subsequently processed and interpreted making use of Excel.

4. Results

No	Time	Environment	**Scenario 1**	Ice 1	**Scenario 2**	Ice 2	BUB 2	**Scenario 3**	Ice 3	BUB 3	REP 3
1	9.00	19.1	**-2.7**	-3.0	**-2.7**	-3.0	9.8	**-2.7**	-3.0	9.8	9.8
2	10.00	19.3	**-2.2**	-2.6	**-2.4**		6.8	**-2.5**			16.8
3	11.00	19.3	**-2.1**	-2.4	**-2.5**		9.0	**-2.5**			16.5
4	12.00	19.2	**-1.9**	-2.2	**-2.5**	-2.3	8.7	**-2.4**	-1.7	7.5	16.7
5	13.00	19.3	**-1.4**	-0.8	**-1.9**		7.0	**-2.3**		10.5	16.1
6	14.00	19.3	**-0.7**	-0.8	**-1.5**		7.2	**-2.2**		9.5	16.3
7	15.00	19.3	**0.0**	-0.6	**-1.3**	-1.3	8.8	**-1.5**	-1.6	8.8	16.7
8	16.00	19.4	**1.2**	0.9	**-0.2**		7.5	**-0.4**			17.0
9	17.00	19.4	**2.2**	1.2	**0.8**		8.2	**0.4**			17.5
10	18.00	19.8	**4.0**	1.5	**1.5**	0.0	10.0	**1.2**	-0.4	14.2	18.8
11	19.00	22.7	**6.7**	6.7				**3.6**			20.2
12	20.00	22.6	**8.4**	8.1				**5.8**			20.7
13	21.00	22.4	**10.9**	10.2				**8.9**			21.0
14	22.00	22.7	**15.4**	14.3				**11.6**	11.4	15.9	21.2

Table 1 measured data from test

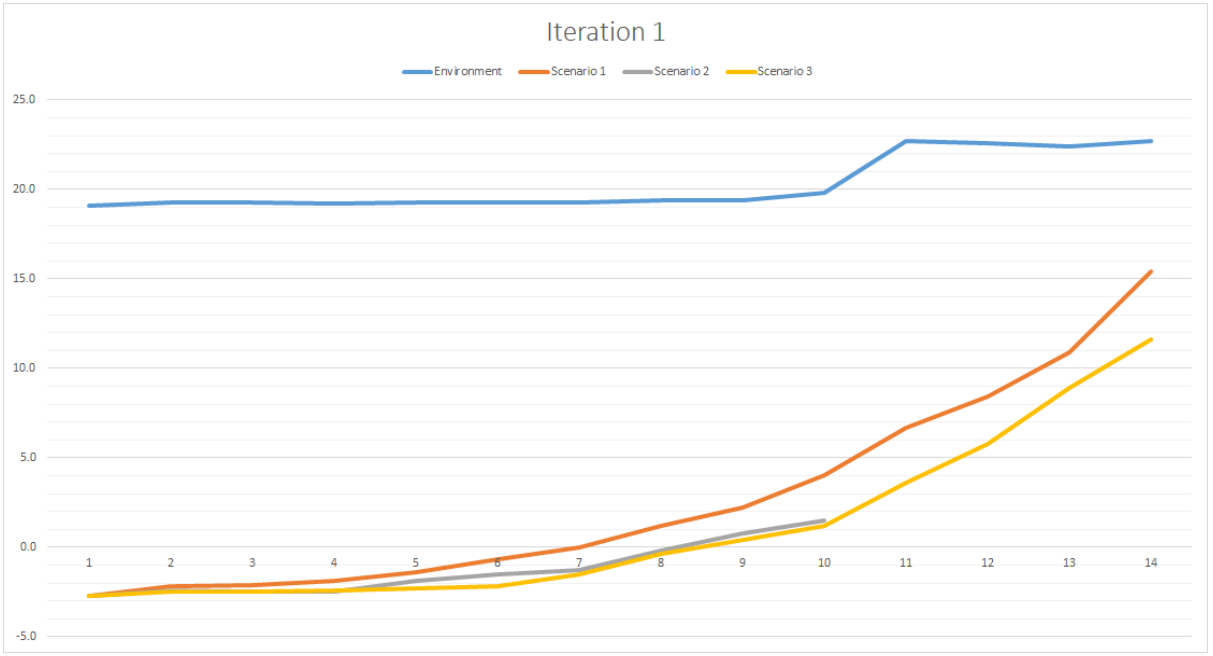


Figure 1 graphical display of measured data

5. Discussion

5.1. Research Questions

The goal of this test was to answer the following questions.

> *What influence does an enclosed air layer have on the temperature trajectory of frozen food?*

The measured data shows a distinction between scenario 1 (without insulation) and scenario 2 (BUBL Bag). The described trajectory of scenario 2 shows a less steep incline in temperature. However, this difference is minimal. Scenario 1 reaches 5 degrees Celsius after 10.5 hours whereas scenario 2 reaches this temperature after almost 12 hours. This suggests the influence of the enclosed air layer is apparent, however it is considered minimal.

> *What influence does an extra outer layer have on the temperature trajectory of frozen food?*

As visible in the graph, the trajectory of scenario 2 and 3 follow somewhat the same line. This suggests that the outer layer has little effect on the insulative performance of the BUBL Bag.

5.2. Limitations

This study provides an insight into the insulative performance of the BUBL Bag. However some limitations need to be considered during the interpretation of these results and the subsequent conclusions.

- *Ice pack started leaking and bag deflated*

After 10 hours of testing, the ice pack in scenario 2 started leaking. In addition the bag deflated a little as well, due to the repeated in- and deflating to measure the temperature. Both affected the measurements from that point on and therefore these measurements are excluded from the dataset. The conclusions are therefore drawn from a less extensive dataset which could affect the accuracy of this test.

- Inflating and deflating

To measure the temperature properly, the bags needed to be deflated in order to take the product out. This procedure exposed the product for a short amount of time to the environment, which is estimated to have little effect on the trajectory. However, during the procedure of deflating and re-inflating cold air is replaced with warm air. This could affect the trajectory negatively causing the temperature to drop faster.

- Infrared thermometer

Infrared thermometers only measure the surface temperature. This temperature could differ drastically depending on the point of measurement. Although making use of a predefined point of measurement, data differed depending on the exact location. Therefore it was chosen to aim for the coldest spot in the predefined region. This shows a somewhat accurate trajectory.

5.3. Improvements

This research provides insights into the insulative performance of an enclosed air layer. However, the performance is not desired. The following improvements are proposed for future testing.

- *Multiple chambers*

Adding more chambers on top of eachother with a bad conducting material in between will decrease the chance of convective flow happening. As a result, it takes longer before the state of equilibrium is reached. This is validated by making use of the parametric model.

Thickness Insulative layer	8 cm	2 x 4 cm
Time till 5 degrees Celsius	24 Hours	41 Hours

**Although the parametric model still needs improvements for a more realistic data output. This relative difference shows potential for further investigation.*

- *Fiber*

In addition, using fibers as a proven insulative layer needs to be considered. This puts the performance of the air insulation principle into perspective as they can be compared relatively.

6. Conclusion

This research provides insights into the insulative performance of an enclosed air layer. The effects of different layers can be assessed. An enclosed air layer in the tested configuration works minimally as an insulative layer. Adding an extra outer layer also adds little insulation. Further testing with the proposed improvements is required to optimize the performance of the insulative layer.

Chamber and Fiber Testing

1. Research objective

The goal of this research is to get a better understanding of the insulative performance of the improved bag-in-bag concept with multiple chambers and the concept with fiber insulation. More specifically, how long are these concepts capable of keeping the product under 5 degrees Celsius. In order to do so, a test is designed to discover the insulative effect of both the enclosed air layers and fiber insulation.

2. Research Question

2.1. What influence does two enclosed air layers have on the temperature trajectory of frozen food?

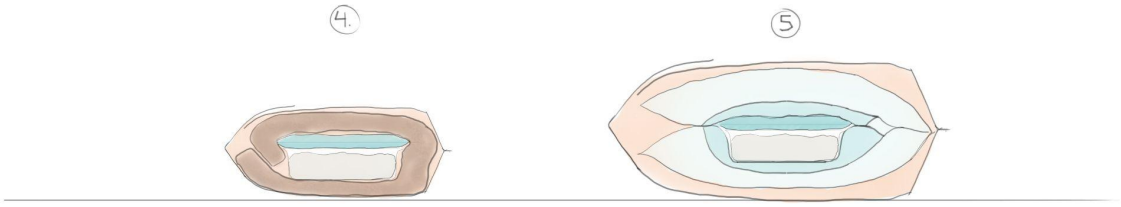
2.2. What influence does fiber insulation have on the temperature trajectory of frozen food?

3. Method

3.1. Research Setup

In order to answer these question the following test is conducted with two different scenarios based on the test described in appendix XX:

1. Product with cooling pack in two bubl bags and a Repack
2. Product with cooling pack in a fiber insulation layer and a Repack



Both scenarios are tested simultaneously to decrease the influence of environmental influences.

3.1.1. Apparatus

Frozen Spicy tofu chunks (200 g) (2x) - to act as the product that needs to be cooled
Ice packs (400 ml) (2x) - to act as a coolant inside the packaging
Bubl Bag (30 x 20 cm) (1x) - to simulate the inner enclosed air cushion
Bubl Bag (40 x 40 cm) (1x) - to simulate the outer enclosed air cushion
Repack (2x) - to simulate the outer bag
Infrared thermometer - To measure surface temperature

3.1.2. Procedure

The temperature of the product cannot be measured through the insulation layer. Therefore, the bag needs to be deflated before the product can be taken out for measurement. Due to this fact, the following procedure is chosen to interrupt the process as little as possible while generating enough data to form good conclusions.

The following temperatures are measured with a three-hour interval:

Environmental temperature

Chamber

- Ice temperature
- Product temperature

Fiber

- Ice temperature
- Product temperature

3.1.3. Data collection

Data is collected with the thermometer following the described procedure. The temperature is measured at predefined locations on the objects. The data is subsequently processed and interpreted making use of Excel.

3. Results

No	Time	Environment	Fiber	Ice 1	Bag in bag	Ice 2
1	9.00	19.1	**-3.7**	-5.5	**-3.7**	-5.5
2	10.00	19.0	**-3.6**	-5.7	**-3.4**	-5.4
3	11.00	19.1	**-3.4**	-5.6	**-3.1**	-5.4
4	12.00	19.2	**-3.4**	-5.7	**-2.9**	-5.3
5	13.00	19.2	**-3.4**	-5.8	**-2.6**	-4.5
6	14.00	19.2	**-3.2**	-5.7	**-2.2**	-4.1
7	15.00	19.2	**-2.9**	-5.6	**-1.6**	-3.8
8	16.00	19.2	**-2.9**	-5.3	**-0.9**	-3.1
9	17.00	19.4	**-2.7**	-5.0	**0.5**	-2.5
10	18.00	19.5	**-2.5**	-4.8	**1.8**	-2.0
11	19.00	20.3	**-2.5**	-4.2	**2.0**	-1.5
12	20.00	20.7	**-2.2**	-2.8	**2.5**	-0.9
13	21.00	21.8	**-2.0**	-2.5	**3.3**	0.2
14	22.00	21.7	**-1.2**	-2.7	**5.2**	1.4
15	23.00	21.5	**-0.4**	-2.4	**6.1**	3.9
16	24.00	20.5	**0.8**	-2.7	**7.2**	5.4
17	25.00	20.4	**0.8**	-2.3		
18	26.00	20.3	**0.9**	-2.0		
19	27.00	20.2	**1.0**	-1.7		
20	28.00	20.1	**1.1**	-1.4		
21	29.00	20.0	**1.2**	-1.2		
22	30.00	19.8	**1.3**	-1.1		
23	31.00	19.7	**1.4**	-1		
24	32.00	19.6	**1.5**	-0.9		
25	33.00	19.2	**1.9**	-0.7		
26	34.00	19.4	**2.2**	-0.5		
27	35.00	18.9	**2.5**	0.0		
28	36.00	20.2	**3.9**	1.6		
29	37.00	20.3	**4.3**	2.8		
30	38.00	20.4	**5.8**	4.2		
31	39.00	20.6	**6.7**	6.1		
32	40.00	20.7	**8.5**	7.8		
33	42.00	20.8	**10.2**	9.2		
34	43.00	20.9	**11.8**	10.7		

Table 1 measured data from test

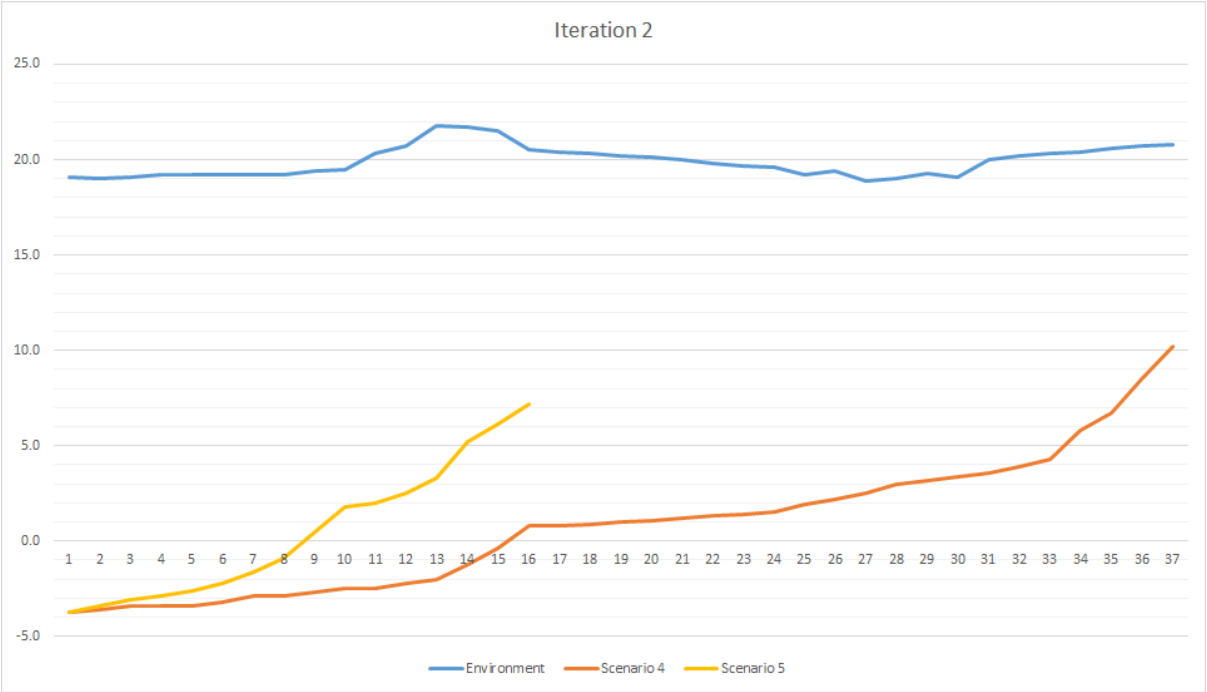


Figure 1 graphical display of measured data

4. Discussion

4.1. Research Questions

The goal of this test was to answer the following questions.

What influence does two enclosed air layers have on the temperature trajectory of frozen food?

The double enclosed air layer in scenario 5 shows a minor improvement in insulative performance (14 Hr) compared to the single bag test performed in iteration 1 (12 Hr). Extrapolating this line would suggest that adding more chambers will increase the insulative performance. This is in line with other insulators like EPS, which consists of a large amount of small enclosed air pockets.

What influence does fiber insulation have on the temperature trajectory of frozen food?

Fibers act as an excellent insulator (34 Hr), compared scenario 1 (10.5 Hr). Due to its structure it creates a large amount of air pockets which decreases the heat flow in the material.

4.2. Limitations

This study provides an insight into the insulative performance of a double air chamber insulation layer and a fiber insulation layer. However some limitations need to be considered during the interpretation of these results and the subsequent conclusions.

- Inflating and deflating

To measure the temperature properly, the bags needed to be deflated in order to take the product out. This procedure exposed the product for a short amount of time to the environment, which is estimated to have little effect on the trajectory. However, during the procedure of deflating and re-inflating cold air is replaced with warm air. This could affect the trajectory negatively causing the temperature to drop faster.

- Infrared thermometer

Infrared thermometers only measure the surface temperature. This temperature could differ drastically depending on the point of measurement. Although making use of a predefined point of measurement, data differed depending on the exact location. Therefore it was chosen to aim for the coldest spot in the predefined region. This shows a somewhat accurate trajectory.

4.3. Improvements

Further improvements would require testing with different types and amounts of products and coolant. In addition the thickness and type of fibers need to be tested in order to select the optimal material.

5. Conclusion

This research provides insights into the insulative performance of a multiple air chamber insulation layer and fiber insulation. The fiber insulation performs substantially better than an (multi chamber) enclosed air insulation layer.

BOKS Performance testing

1. Research objective

The goal of this research is to get a better understanding of the insulative performance of BOKS compared to the parametric model. More specifically, how well does the model represent real world data. In order to do so, a test is designed to measure the insulative performance of BOKS.

2. Research Question

2.1. How long is BOKS capable of keeping frozen products under 5 degrees Celsius? And how does that compare to the parametric model?

2.2. How does this differ per type of product?

3. Method

3.1. Research Setup

In order to answer this question the following test is conducted for a scenario with 1.2 kg of food and 5 ice packs.

Hypothesis

Based on the parametric model this setup is expected to stay under 5 degrees Celsius for 24 hours. At a constant environment temperature of 21 degrees. It is expected that the dense products will remain their temperature for longer compared to the loosely packed products.

3.1.1. Apparatus

Frozen Spicy tofu chunks (200 g) (2x), Frozen Tofu Natural (200 g) (2x) and Frozen Vegetarian meat balls (200 g) (2x) - to act as the product that needs to be cooled
Ice packs (300 ml) (5x) - to act as a coolant inside the packaging
BOKS - To act as insulation barrier
Infrared thermometer - To measure surface temperature

3.1.2. Procedure

The following temperatures are measured with a one-hour interval:

- Environmental temperature
- Ice temperature
- Product temperature

3.1.3. Data collection

Data is collected with the thermometer following the described procedure. The temperature is measured at predefined locations on the objects. The data is subsequently processed and interpreted making use of Excel.

1. Results

No	Time	Environment	Product	Ice Top	Ice Bottom	Spicy Tofu	Model
0	10.00	22.2	**-15.9**	-16.2			**-18.0**
1	11.00	22.2	**-16.0**	-16.0			**-14.5**
2	12.00	22.4	**-14.6**	-13.9			**-11.5**
3	13.00	23.2	**-12.4**	-10.6			**-9.6**
4	14.00	22.9	**-9.6**	-8.0			**-8.1**
5	15.00	23.3	**-8.8**	-5.7			**-6.8**
6	16.00	23.5	**-7.6**	-4.3			**-5.7**
7	17.00	23.7	**-6.9**	-3.7			**-4.8**
8	18.00	24.1	**-6.0**	-3.2			**-4.0**
9	19.00	24.3	**-5.7**	-3.1			**-3.3**
10	20.00	24.7	**-5.7**	-2.9			**-2.6**
11	21.00	24.1	**-5.3**	-2.4			**-1.9**
12	22.00	23.7	**-5.5**	-2.6			**-1.3**
13	23.00	23.7	**-5.0**	-2.1			**-0.7**
14	00.00	23.2	**-5.2**	-1.7			**-0.1**
15	*01.00*	*23.0*	***-5.0***	*-1.5*			**0.5**
16	*02.00*	*23.0*	***-4.9***	*-1.3*			**1.0**
17	*03.00*	*23.0*	***-4.8***	*-1.2*			**1.6**
18	*04.00*	*23.0*	***-4.6***	*-1*			**2.1**
19	*05.00*	*23.0*	***-4.5***	*-0.8*			**2.6**
20	*06.00*	*23.0*	***-4.4***	*-0.6*			**3.1**
21	*07.00*	*23.0*	***-4.1***	*-0.4*			**3.6**
22	*08.00*	*23.0*	***-3.8***	*-0.2*			**4.1**
23	09.00	23.3	**-3.6**	0.0	0.2	-4.3	**4.5**
24	10.00	23.3	**-3.0**	0.5	0.8	-4.1	**5.0**
25	11.00	23.5	**-2.4**	0.8	1.1	-3.6	**5.4**
26	12.00	23.7	**-1.7**	1.2	1.1	-3.5	**5.8**

27	13.00	23.6	**-0.6**	1.9	1.4	-3.2	**6.3**
28	14.00	24.2	**-0.9**	2.1	1.7	-3.1	**6.7**
29	15.00	24.0	**-0.5**	2.9	2.1	-2.9	**7.1**
30	16.00	24.3	**-0.2**	3.2	2.6	-2.8	**7.4**
31	17.00	24.0	**1.0**	4.9	3.5	-2.6	**7.8**
32	18.00	23.8	**2.1**	5.1	4.6	-2.6	**8.2**
33	19.00	24.9	**1.9**	7.2	5.7	-2.3	**8.5**
34	20.00	25.3	**2.3**	6.8	6.1	-2.1	**8.9**
35	21.00	24.2	**2.9**	7.0	6.5	-2.1	**9.2**
36	22.00	23.8	**3.2**	6.9	6.8	-1.8	**9.5**
37	23.00	24.4	**4.4**	8.8	7.5	-1.6	**9.9**
38	00.00	24.0	**5.0**	9.4	8.0	-1	**10.3**

Table 1 measured data from test

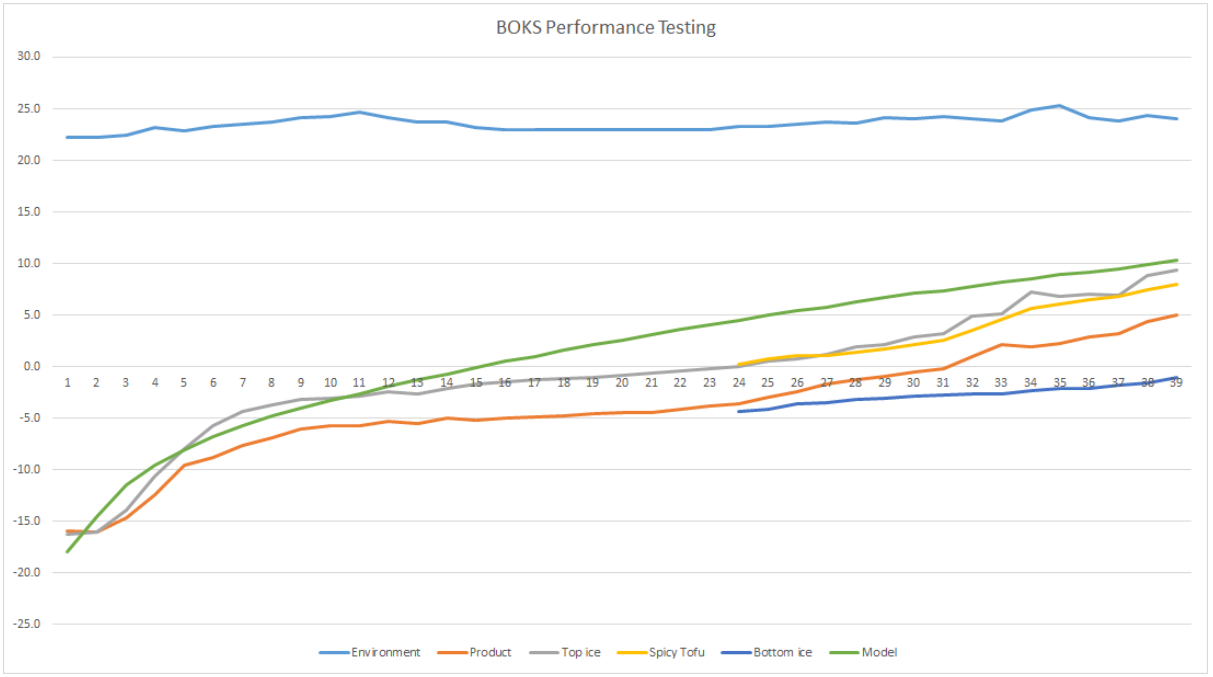


Figure 1 graphical display of measured data

2. Discussion

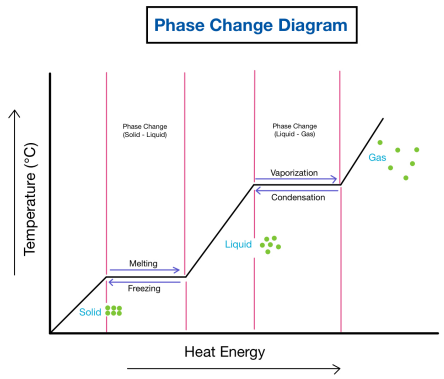
2.1. Research Questions

The goal of this test was to answer the following questions.

How long is BOKS capable of keeping frozen products under 5 degrees Celsius? And how does that compare to the parametric model?

From the test data it can be concluded that BOKS is capable of keeping the selected products under 5 degrees for at least 32 to 38 hours depending on the type of product. Compared to the hypothesis of 24 hours this is quite a big difference. The parametric model does not calculate extremely realistic results as expected given the drastic simplifications made.

In addition, the path of the line in the parametric model is fluent almost like a root function. Whereas the path of the measured data resembles the shape of a phase change diagram. To make the parametric model resemble real world data more, various improvements are suggested.



How does this differ per type of product?

As expected, the loosely spicy tofu bits heat up faster compared to the dense natural tofu. Since the packaging is more compact and does not involve additional air, the natural tofu is capable of retaining its temperature for 38 hours, compared to the 32 hours of the loosely packed tofu.

2.2. Limitations

This study provides an insight into the insulative performance of BOKS and compares it to the parametric model. This data can act as input to further improve the model. However some limitations need to be considered during the interpretation of these results and the subsequent conclusions.

- Opening of BOKS

To measure the temperature properly, BOKS needs to be opened every hour. This procedure exposes the product for a short amount of time to the environment. This is estimated to have a minor effect on the trajectory due to its volatility, although a setup without opening would be prefered.

- Infrared thermometer

Infrared thermometers only measure the surface temperature. This temperature could differ drastically depending on the point of measurement. Although making use of a predefined point of measurement, data differed depending on the exact location. Therefore it was chosen to aim for the coldest spot in the predefined region. This shows a somewhat accurate trajectory.

2.3. Improvements

Further improvements would require testing with different types and amounts of products and coolant.

The parametric model can be improved by making thermodynamic values time dependent. Ice for example has a different specific heat capacity and heat transfer coefficient depending on its phase and temperature. This is not included in the model. Incorporating this in the model will make the data more realistic as the curvature resembles the phase change diagram more.

3. Conclusion

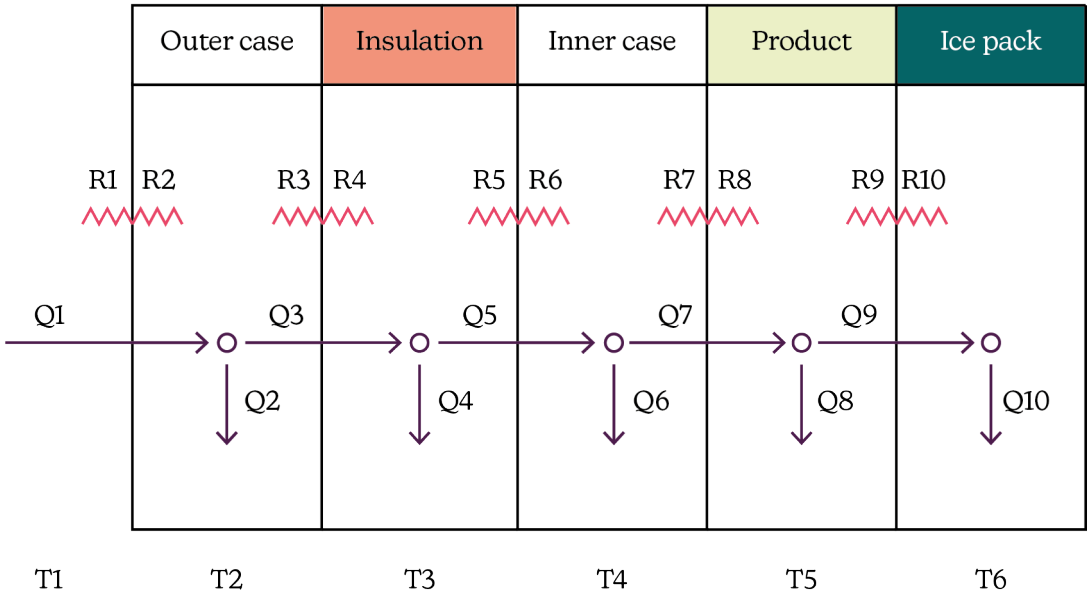
This research provides insights into the insulative performance of BOKS. The performance is better compared to the parametric model in the way it keeps products cooler for longer. The parametric model can be improved further to make it more realistic.

Appendix D

Parametric model for thermodynamic analysis

```
> restart;
```

Simplifications and assumptions



Parametric

Equations

```
> #Heat in - Heat absorbed - Heat out =0
> Eq1 := q1 - q2 - q3 = 0 :
> Eq2 := q3 - q4 - q5 = 0 :
> Eq3 := q5 - q6 - q7 = 0 :
> Eq4 := q7 - q8 - q9 = 0 :
> Eq5 := q9 - q10 = 0 :
>
```

$$> q1 := \frac{(T1 - T2(t))}{R1 + R2} :$$

$$q2 := Mopp \cdot Cpp \cdot diff(T2(t), t) :$$

$$q3 := \frac{(T2(t) - T3(t))}{R3 + R4} :$$

$$q4 := Mfib \cdot Cfib \cdot diff(T3(t), t) :$$

$$q5 := \frac{(T3(t) - T4(t))}{R5 + R6} :$$

$$q6 := Mipp \cdot Cpp \cdot diff(T4(t), t) :$$

$$q7 := \frac{(T4(t) - T5(t))}{R7 + R8} :$$

$$q8 := Mprod \cdot Cprod \cdot diff(T5(t), t) :$$

$$q9 := \frac{(T5(t) - T6(t))}{R9 + R10} :$$
$$q10 := Mice \cdot Cice \cdot diff(T6(t), t) :$$

Resistances

> $$R1 := \frac{1}{Hair \cdot A1} :$$
$$R2 := \frac{\left(\frac{L1}{2}\right)}{Kpp \cdot A1} :$$
$$R3 := \frac{\left(\frac{L1}{2}\right)}{Kpp \cdot A2} :$$
$$R4 := \frac{\left(\frac{L2}{2}\right)}{Kfib \cdot A2} :$$
$$R5 := \frac{\left(\frac{L2}{2}\right)}{Kfib \cdot A3} :$$
$$R6 := \frac{\left(\frac{L3}{2}\right)}{Kpp \cdot A3} :$$
$$R7 := \frac{\left(\frac{L3}{2}\right)}{Kpp \cdot A4} :$$
$$R8 := \frac{\left(\frac{L4}{2}\right)}{Kprod \cdot A4} :$$
$$R9 := \frac{\left(\frac{L4}{2}\right)}{Kprod \cdot A5} :$$
$$R10 := \frac{\left(\frac{L5}{2}\right)}{Kice \cdot A5} :$$

Surface Areas & Mass

> $$A1 := 2 \cdot (((Lc + v) \cdot (Bc + v)) + ((Lc + v) \cdot (Wc + v)) + ((Wc + v) \cdot (Bc + v))) :$$
$$A2 := 2 \cdot (((Lc + u) \cdot (Bc + u)) + ((Lc + u) \cdot (Wc + u)) + ((Wc + u) \cdot (Bc + u))) :$$
$$A3 := 2 \cdot (((Lc + w) \cdot (Bc + w)) + ((Lc + w) \cdot (Wc + w)) + ((Wc + w) \cdot (Bc + w))) :$$
$$A4 := 2 \cdot ((Lc \cdot Bc) + (Lc \cdot Wc) + (Wc \cdot Bc)) :$$
$$A5 := 2 \cdot (0.2 \cdot 0.15) \cdot Packs :$$

>

> $$w := 2 \cdot L3 :$$

> $$u := 2 \cdot (L3 + L2) :$$

> $$v := 2 \cdot (L3 + L2 + L1) :$$

```
> 
> Vfib := (Lc + u)·(Bc + u)·(Wc + u) − (Lc + w)·(Bc + w)·(Wc + w) :
  Vopp := (Lc + v)·(Bc + v)·(Wc + v) − (Lc + u)·(Bc + u)·(Wc + u) :
  Vipp := (Lc + w)·(Bc + w)·(Wc + w) − (Lc·Bc·Wc) :
> 
> Mopp := rhopp·Vopp :
  Mipp := rhopp·Vipp :
> Mfib := rhofib·Vfib :
> Mice := rhoice·Packs·0.4·10^-3 :
> 
> 
```

Review

```
> Eq1 :
> Eq2 :
> Eq3 :
> Eq4 :
> Eq5 :
```

Numeric

```
> #Numeric values (CES Edupack)
> Hair := 25 : T1 := 21 :
  Cpp := 1670 : Kpp := 0.2 : rhopp := 899 :
  Cfib := 1200 : rhofib := 1.42 : Hair := 5 : Kfib := 0.2 :
  rhoice := 916 :  Kice := 2.07 : Cice := 2080 :
> 
> #Define volume of cooled space
> Lc := 0.334 : Bc := 0.234 : Wc := 0.134 :
> 
> #Define thickness of insulating layer
>  L1 := 0.004 : L2 := 0.025 : L3 := L1 : L4 := Bc : L5 := 0.015 :
> #Define content of cooling
> Mprod := 3 : Cprod := 1670 : Kprod := 0.43 :
> #Define amount of coolant
> Packs := 5
```

$$Packs := 5 \tag{2.1}$$

```
> 
> #Numeric values (SolidWorks Model)
> 
> 
```

Review

```
> A1; A2; A3; A4; A5;
```

0.520000

0.491584

$$0.331384$$
$$0.308536$$
$$0.300 \tag{2.1.1}$$

> $Vfib; Mtot := Mopp + Mipp + Mfib;$

$$0.010224600$$
$$Mtot := 2.983462836 \tag{2.1.2}$$

> $Eq1;$

$$52.00000000 - 9.256659444\, T2(t) - 3037.058473\, \frac{d}{dt} T2(t) + 6.780468968\, T3(t) = 0 \tag{2.1.3}$$

> $Eq2;$

$$6.780468968\, T2(t) - 11.35128276\, T3(t) - 17.42271840\, \frac{d}{dt} T3(t) + 4.570813794\, T4(t) = 0 \tag{2.1.4}$$

> $Eq3;$

$$4.570813794\, T3(t) - 5.664552294\, T4(t) - 1921.077847\, \frac{d}{dt} T4(t) + 1.093738500\, T5(t) = 0 \tag{2.1.5}$$

> $Eq4;$

$$1.093738500\, T4(t) - 2.181813801\, T5(t) - 5010\, \frac{d}{dt} T5(t) + 1.088075301\, T6(t) = 0 \tag{2.1.6}$$

>

Initial Conditions

> $ics := T2(0) = (T1 \cdot 0.8), T3(0) = (T1 \cdot 0.6), T4(0) = (T1 \cdot 0.5), T5(0) = -18, T6(0) = -18 :$

>

Solve

> $sol1 := dsolve(\{Eq1, Eq2, Eq3, Eq4, Eq5, ics\}, \{T2(t), T3(t), T4(t), T5(t), T6(t)\}, numeric, output = listprocedure, maxfun = 5000000) :$

> $T2 := rhs(sol1[2]) :$

> $T3 := rhs(sol1[3]) :$

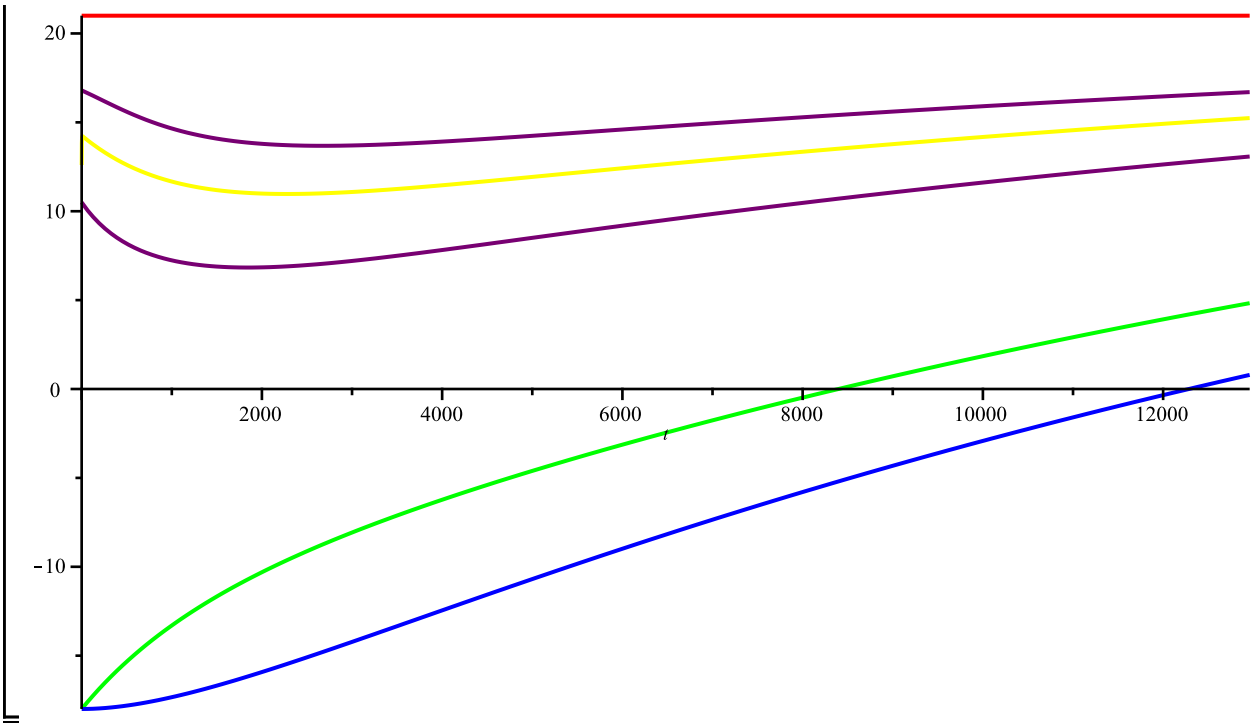
> $T4 := rhs(sol1[4]) :$

> $T5 := rhs(sol1[5]) :$

> $T6 := rhs(sol1[6]) :$

>

> $plot([T1, T2(t), T3(t), T4(t), T5(t), T6(t)], t = 0..(360 \cdot 36), color = [red, purple, yellow, purple, green, blue], style = line);$




```
>
> seconds := fsolve(T5(t) = 5) :
> hours := seconds/360;
```

$$hours := 36.51609511 \qquad \textbf{(2.3.1)}$$

```
> #seconds8:=fsolve(T5(t) = 10.5) :
  # hours8:=seconds8/360;
>
>
>
>
```

Appendix E

Fast track lifecycle analysis

LCA tool (Life Cycle Assessment)

Community of Practice Reusable Packaging

Netherlands Institute for Sustainable Packaging

Background

In order to further investigate challenges and opportunities of reusable packaging, the Netherlands Institute for Sustainable Packaging (KIDV) has set up the Community of Practice Reusable Packaging. Companies often struggle with the fact that they individually have too little impact to realise changes in the packaging supply chain. In a Community of Practice (CoP) challenges are tackled jointly.

This LCA tool is developed to support the members of the CoP to get a quick indication of the CO2 impact of the reusable packaging compared to one or more single use alternatives. The tool is being developed for KIDV by Partners for Innovation and Utrecht University, in cooperation with the members of the CoP Reusable Packaging.

How to use the LCA tool?

1. INPUT
Go to the INPUT sheet and fill in all available data of the reusable packaging and single-use alternative

2. More reference packaging
If you want to compare more than one single-use reference packaging systems you can use this next sheet. This is optional.

3. Results CO2 impact
See the results of the CO2 impact of the reusable and single-use packaging system.

4. Results cost
See the results of the packaging costs per cycle and the break-even point.

5. Data
Check the data that is used for the calculations.

Help

To help you fill in and understand the tool, hints and explanations are given in the INPUT and Results sheets. When you select an open entry cell for the reusable packaging, a yellow box with explanation will be shown. When there are a few repeated options, only the top cell has the explanation.

Try here

At other points that might require explanation, you can find cells with *Help* in them. Selecting this cell will also open a yellow box with an explanation.

Help

Assumptions:

> This tool works with average LCA data (sources listed in Data tab) and is based on assumptions by the user. So the results can only give a rough indication of the CO2 impact of the packaging systems.

> The return rate does not only determine the number of average use cycles, it also influences the impact of cleaning, impact of return transport, and end-of-life scenario.

> It is assumed that the unreturned reusable packaging will enter the Dutch municipal waste stream and is taken into account accordingly.

> Transport is calculated based on mass, not volume. When you have a very voluminous packaging with a low density, this will distort the accuracy of the calculation.

> The impact of the used energy is based on the average impact of electric energy consumption in The Netherlands.
> Road transport is calculated by using vehicles with the highest EU standard (Euro6).

> Aluminium is used as virgin material, and this will be recycled to other products but not in packaging applications.
> Impact of bioplastics is based on calculation with values from Chen and Patel (2012). This study did not include the effects of land use change, i.e. it is not taken into account that forest is cleared to grow the crops.

Disclaimer

Colofon:

©2020 version 1.0, this tool is made by Partners for Innovation in cooperation with University Utrecht for KIDV

Authors: Jannes Nelissen, Siem Haffmans (Partners for Innovation) / Ernst Worrell, Patricia Megale Coelho and Blanca Corona Bellostas (University Utrecht)

LCA tool (Life Cycle Assessment)

Community of Practice Reusable Packaging

Netherlands Institute for Sustainable Packaging

Reusable packaging

name: BOKS

Volume of packed product (L) — *text input*: 24 liter

Return rate (%) — *text input*: 80%

Technical lifespan (number of use cycles) — *text input*: 100 cycles

Packaging production

Tip: this can include secondary and tertiary packaging.

Part name *Optional text input*	material *dropdown*	mass (g) *text input*	recycled content (%) *text input*	process step *dropdown*	Single-use item? *checkbox*	Packaging costs Costs per item in € *text input*
Case	PP	2000	40%	Injection moulding		€ 13.00
Insulation	HEMP fiber	15				€ 2.00
						€ -
						€ -

Help

Transport to product producer or filler

Transportation mode *dropdown*	Distance (km) *text input*	Mass of packaging (g) *optional text input*	**Cost** of transport (€) *text input*		*number of products*
Lorry >32ton	150		€ 25.00	per	300
			€ -	per	
			€ -	per	

Filling of packaging

No significant CO2 impact is expected, when compared to single-use packaging.

Transport to DC

Transportation mode *dropdown*	Distance (km) *text input*	Mass of packaging (g) *optional text input*	**Cost** of transport (€) *text input*		*number of products*
Electric car	20		€ 10.00	per	50
			€ -	per	

Storage

No significant CO2 impact is expected, when compared to single use packaging.

Optional input for significant extra costs.

€ - per

Distribution to customer

Transportation mode *dropdown*	Distance (km) *text input*	Mass of packaging (g) *optional text input*	**Cost** of distribution (€) *text input*		*number of products*
Electric car	100		€ 8.95	per	1
			€ -	per	

Consumption of product

No significant CO2 impact is expected, when compared to single use packaging.

Return transport

Transportation mode *dropdown*	Distance (km) *text input*	Mass of packaging (g) *optional text input*	**Packaging is reused by customer and not returned to filler.** *checkbox*	**Cost** of return transport (€) *text input*		*number of products*
Electric car	100			€ 25.00	per	50
				€ -	per	
				€ -	per	

Help

Cleaning

Volume of cleaned packaging (L) — 24

Single-use packaging

name: Cardboard box

Volume of packed product (L) — *text input*: 24 liter

Packaging production

Part name *Optional text input*	material *dropdown*	mass (g) *text input*	recycled content (%) *text input*	process step *dropdown*	Packaging costs Costs per item in € *text input*
Box	Corrugated board	400		Cardboard box folding	€ 0.50
Insulation	unbleached paper	100	100%		€ 0.80
					€ -
					€ -
					€ -

Transport to product producer or filler

Transportation mode *dropdown*	Distance (km) *text input*	Mass of packaging (g) *optional text input*	**Cost** of transport (€) *text input*		*number of products*
Lorry >32ton	150		€ 25.00	per	300
			€ -	per	
			€ -	per	

Filling of packaging

No significant CO2 impact is expected, when compared to reusable packaging.

Transport to DC

Transportation mode *dropdown*	Distance (km) *text input*	Mass of packaging (g) *optional text input*	**Cost** of transport (€) *text input*		*number of products*
Electric car	20		€ 10.00	per	50
			€ -	per	

Storage

No significant CO2 impact is expected, when compared to reusable packaging.

Optional input for significant extra costs.

€ - per

Distribution to customer

Transportation mode *dropdown*	Distance (km) *text input*	Mass of packaging (g) *optional text input*	**Cost** of distribution (€) *text input*		*number of products*
Electric car	100		€ 8.95	per	1
			€ -	per	

Consumption of product

No significant CO2 impact is expected, when compared to reusable packaging.

Skip to end of Life

Skip to end of Life

Percentage of returned packaging that is cleaned.

Cleaning method *dropdown list*	Return rate is already taken into account. *optional text input*	**Cost** of cleaning (€) *text input*		*number of products*
Inspection	100%	€ 20.00	per	30
Industrial washing (NaOH solution)	10%	€ 20.00	per	50
		€ -	per	

Transportation to End-of-life

Additional transportation to End-of-life

Transportation mode *dropdown*	Distance (km) *text input*	Mass of waste (g) *optional text input*	**Cost** of transportation (€) *text input*		*number of products*
Van (<3,5 ton)	50		€ 25.00	per	50
			€ -	per	

End-of-life processes

Materials *automatically filled*	End-of-life scenario *dropdown list*	Disposal costs (€ per ton) *text input*
#N/A	Recycling	€ 10.00
#N/A	Incineration	
#N/A		
#N/A		
#N/A		

Transportation to End-of-life

Additional transportation at end of life

Transportation mode *dropdown*	Distance (km) *text input*	Mass of waste (g) *optional text input*	**Cost** of transportation (€) *text input*		*number of products*
Van (<3,5 ton)	50		€ 25.00	per	50
			€ -	per	

End-of-life processes

Materials *automatically filled*	End-of-life scenario *dropdown list*	Disposal costs (€ per ton) *text input*
#N/A	Recycling	€ 10.00
#N/A		
#N/A		
#N/A		
#N/A		

LCA tool (Life Cycle Assessment)

Community of Practice Reusable Packaging

Netherlands Institute for Sustainable Packaging

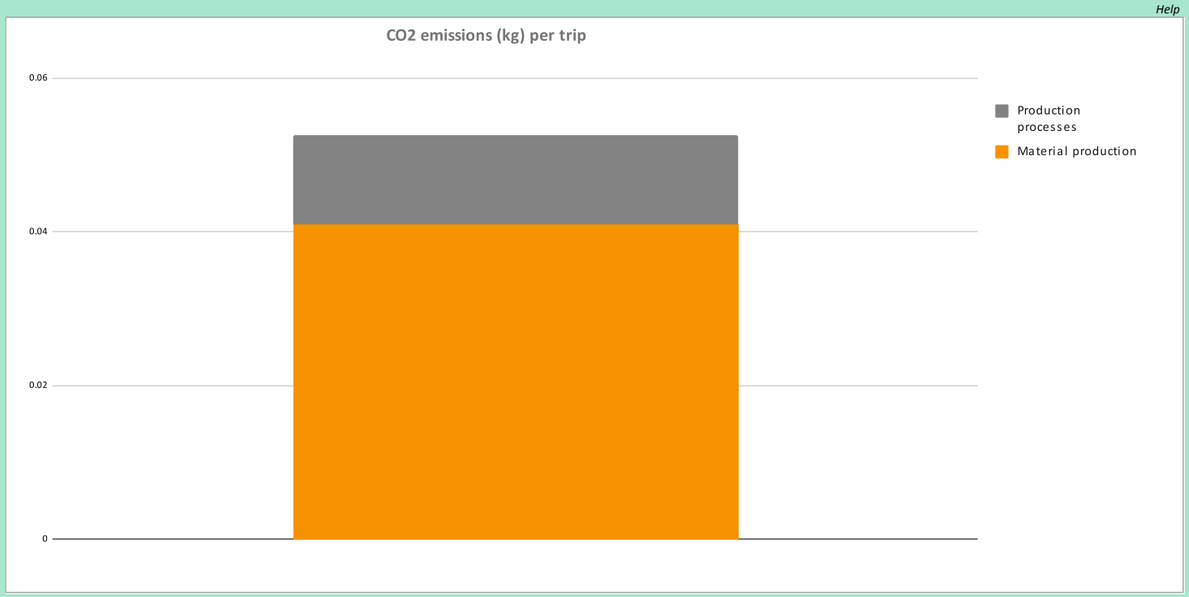
RESULTS

CO2 emissions (kg) per trip

Help *Help*

	Packaging name	Total CO2 emissions (kg)	Extra CO2 emissions (%)	Material production	Production processes	Transport / distribution	Return transport	Cleaning	End-of-life
Reusable packaging	BOKS	1.322	-	0.748	0.570	0.058	0.041	0.012	-0.107
Single use packaging #1	Cardboard box	0.541	-59%	0.553	0.000	0.022	-	-	-0.033
Single use packaging #2	*Single use packaging #2*	*0.000*	*-100%*	*0.000*	*0.000*	*0.000*	-	-	*0.000*
Single use packaging #3	*Single use packaging #3*	*0.000*	*-100%*	*0.000*	*0.000*	*0.000*	-	-	*0.000*

Help



Break-even point *Help*

The reusable packaging contributes to less CO2 equivalent emissions when the packaging is used at least:

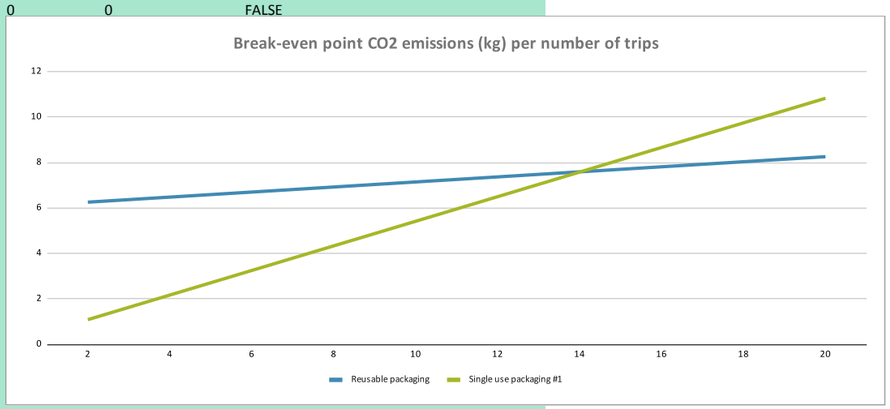
14.0	#N/A
0.0	#N/A
0.0	#N/A

Help

GRAFIEK MAKEN VOOR BREAK-EVEN POINT

hoogste break-even point 14.02373542

	BOKS	Cardboard box	Single use pack	Single use packaging #3	
2	6.252057212	1.082226	0	0	FALSE
4	6.474345592	2.164452			
6	6.696633972	3.246678			
8	6.918922352	4.328904			
10	7.141210732	5.41113			
12	7.363499112	6.493356			
14	7.585787492	7.575582			
16	7.808075872	8.657808			
18	8.030364252	9.740034			
20	8.252652632	10.82226			
11	7.252354922	5.952243			
12	7.363499112	6.493356			
50	11.58697833	27.05565			
100	17.14418783	54.1113			
Emission per cycle	0.1714418783	0.541113			
Reduction	**68.32%**				

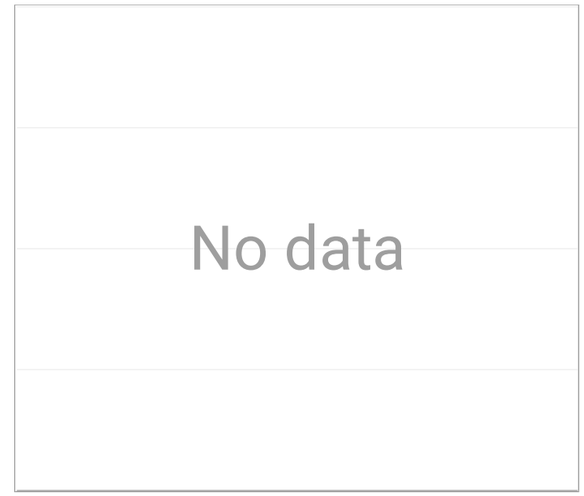


677.59592

1.318

In this calculation is not included:

#N/A
#N/A
#N/A
#N/A
#N/A
#N/A
#N/A
#N/A
#N/A
#N/A
#N/A
#N/A
#N/A
#N/A
#N/A
#N/A
#N/A
#N/A
#N/A
#N/A
#N/A
#N/A
#N/A



LCA tool (Life Cycle Assessment)

Community of Practice Reusable Packaging

Netherlands Institute for Sustainable Packaging

RESULTS

Average cost (€) per packaging item per trip

Help

	Packaging name	Total Costs (€)	Total costs per 24 liter	Production	Transport / distribution	Storage	Return transport	Cleaning	End-of-life	Packaging Volume
Reusable packaging	BOKS	€ 13.30	€ 13.30	€ 3.00	€ 9.01	€ -	€ 0.50	€ 0.71	€ 0.08	24 liter
Single use packaging #1	Cardboard box	€ 11.04	€ 11.04	€ 1.30	€ 9.23	€ -	-	-	€ 0.51	24 liter
Single use packaging #2	*Single use packaging #2*	€ -	*#DIV/0!*	€ -	€ -	€ -	-	-	€ -	*unspecified*
Single use packaging #3	*Single use packaging #3*	€ -	*#DIV/0!*	€ -	€ -	€ -	-	-	€ -	*unspecified*

Break-even point

Help

The reusable packaging is cheaper to use than the single use alternatives when the packaging is used at least:

18.3 #N/A

#N/A
#N/A
#N/A

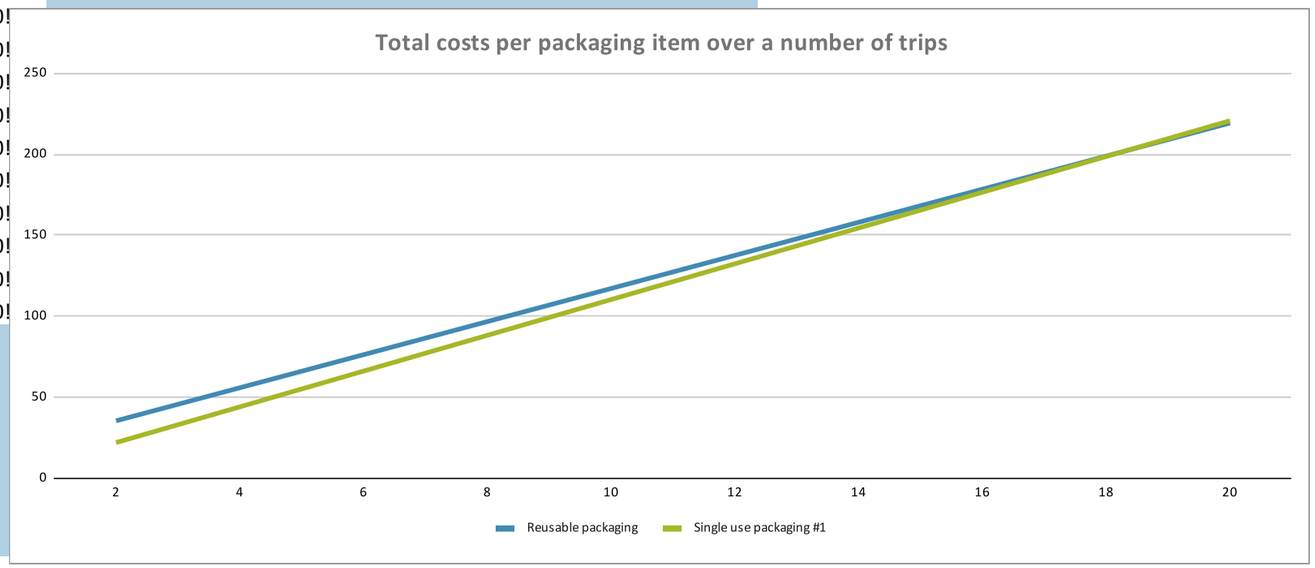
Help

FALSE
FALSE
FALSE
FALSE

GRAFIEK MAKEN VOOR BREAK-EVEN POINT

18.283

	BOKS	Cardboard box	Single use pack	Single use packaging #3
2	€ 35.51	€ 22.08	#DIV/0!	#DIV/0!
4	€ 55.94	€ 44.15	#DIV/0!	#DIV/0!
6	€ 76.36	€ 66.23	#DIV/0!	#DIV/0!
8	€ 96.79	€ 88.31	#DIV/0!	#DIV/0!
10	€ 117.22	€ 110.38	#DIV/0!	#DIV/0!
12	€ 137.64	€ 132.46	#DIV/0!	#DIV/0!
14	€ 158.07	€ 154.54	#DIV/0!	#DIV/0!
16	€ 178.50	€ 176.61	#DIV/0!	#DIV/0!
18	€ 198.92	€ 198.69	#DIV/0!	#DIV/0!
20	€ 219.35	€ 220.77	#DIV/0!	#DIV/0!
50	€ 525.75	€ 551.92		
100	€ 1,036.42	€ 1,103.83		



DATA sheet

Help

PEF calculation	Ev= E*v		A*Erecycled + (1-A) *Ev*(Qs,in/Qp)		ED		(1-A)* (ErecyclingEoL - E*v * (Qs,in/Qp))				A	Qs,in/Qp = Qs, out/Qp		Erecycled = ErecyclingE	ErecyclingEoL		
Material	Production CO2.kg	Source	Recycled CO2.kg	Source	Incineration CO2.kg	Source	Recycling CO2.kg	Source	Average packaging waste CO2.kg	Source	Allocation factor A	Downcycle factor Q	Source	Impact of recycling process		Source	Sources can be found at the bottom of the page.
PET	3.30	1	2.11	3	2.06	1	-0.86	2	0.54	4	0.5	0.9	13	1.25	1.25	1	
PP	2.19	1	1.37	3	2.56	1	-0.60	2	0.92	4	0.5	0.9	14	0.77	0.77	1	
LDPE	2.36	1	0.97	3	3.03	6	-0.20	2	1.35	4	0.8	0.75	14	0.77	0.77	6	
LLDPE	2.09	1	0.93	3	3.03	6	-0.16	2	1.37	4	0.8	0.75	14	0.77	0.77	6	
HDPE	2.17	1	1.36	3	3.03	1	-0.59	2	1.15	4	0.5	0.9	14	0.77	0.77	1	
PS	3.93	1	1.86	3	3.20	1	-1.09	2	3.20	4	0.5	0.75	14	0.77	0.77	1	
BioPE	-0.16	10	0.31	11	3.03	6	0.46	11	1.69	4	0.5	0.9	14	0.77	0.77	6	
BioPP	-1.91	10	-0.47	11	2.56	1	1.24	11	1.87	4	0.5	0.9	14	0.77	0.77	6	
PLA	1.44	10	0.88	3	2.38	1	-0.11	2	2.38	4	0.8	0.9	13	0.77	0.77	6	
Rubber	2.94	1		5	3.16	1	-0.33	2	3.16	4	0.8	0.75	13	0.54	0.54	1	
Flax fiber	0.42		0.25		1.39		-0.05		1.39		0.2	0.75			0.25		
HEMP fiber	1.52		0.91		1.54		-0.71		1.54		0.2	0.75			0.25		
Corrugated board	1.14	1	0.91	3	0.03	1	-0.21	2	-0.18	4	0.2	0.85	13	0.71	0.71	1	
Folding boxboard	1.59	1	1.23	3	0.03	6	-0.50	2	-0.44	4	0.2	0.85	13	0.73	0.73	6	
bleached paper	1.73	1	1.32	3	0.03	1	-0.60	2	-0.52	4	0.2	0.85	13	0.73	0.73	1	
unbleached paper	1.22	1	0.98	3	0.03	6	-0.25	2	-0.22	4	0.2	0.85	13	0.73	0.73	6	
Glass (white)	1.33	1		5	0.03	1	-1.06	2	-0.91	4	0.2	1	13	0.004	0.004	7	
Glass (green)	1.05	1		5	0.03	6	-0.84	2	-0.72	4	0.2	1	13	0.004	0.004	7	
Wood (soft wood)	0.25	9		5	0.02	1	-0.04	2	-0.03	4	0.8	0.9	13	0.004	0.004	9	
MDF (medium density fibre bo	1.11	15		5	0.02	6	-0.20	2	-0.15	4	0.8	0.9	14	0.004	0.004	6	
Aluminium	19.57	1		5	0.26	1	-15.47	2	-14.68	4	0.2	1	13	0.24	0.24	1	
Carbon steel	2.28	1		5	0.07	1	-1.77	2	-1.68	4	0.2	1	13	0.06	0.06	1	
Stainless steel	4.99	1		5	0.07	6	-3.95	2	-3.75	4	0.2	1	13	0.06	0.06	6	
Silicone	3.41	1		5	2.38	6	-0.40	2	2.38	4	0.8	0.75	13	0.54	0.54	1	

Process	Production CO2.kg	Source
Injection moulding	1.43	1
Extrusion blow moulding	1.47	1
Injection blow moulding	1.95	1
Thermoforming	1.18	1
Film extrusion	0.61	1
Calendaring	0.46	1
Cardboard box folding	0.00	12
Deepdrawing aluminium	1.93	1
Deepdrawing steel	1.20	1
Sheet rolling aluminium	0.76	1
Sheet rolling steel	0.44	1
Wood sawing	0.00	12
Glass production	0.00	12

Transportation	CO2.ton.km	Source
Van (<3,5 ton)	1.97	1
Lorry 7,5-16 ton	0.22	1
Lorry 16-32 ton	0.17	1
Lorry >32ton	0.09	1
Train (freight)	0.05	1
Barge (inland)	0.05	1
Transoceanic container ship	0.01	1
Airfreight	1.12	1
Passenger car	0.34	1
Electric car	0.25	1
Electric bike	0.01	1
Walking or cycling	0.00	

Cleaning	CO2.liter	Source	use per liter packagin	use (l)	energy use (MJ)	use (g)	remarks		Tap water (EU) per kg	Soap pe	Sodium hydroxide in 50%	Electricity (NL-mediur	Electricity (NL-low voltage) per MJ				CO2 impact
Inspection	0	8	Inspection	0	0	0			0.0004	6.46	1.40	0.17	0.18				
Industrial washing (NaOH solut	0.006	8	Industrial washing (N	0.27	0.03	2.08	detergent is 50% NaOH		0.0001	0.00	0.00	0.00	0.00				0.01
Industrial grade dishwashing	0.013	8	Industrial grade dishv	0.43	0.07	1.38	detergent is 50% NaOH		0.0002	0.00	0.00	0.01	0.00				0.01
consumer grade dishwashing	0.031	8	consumer grade dishv	0.49	0.15	0.73			0.0002	0.00	0.00	0.00	0.03				0.03
handwashing	0.103	8	handwashing	3.86	0.46	3.48			0.0015	0.02	0.00	0.00	0.08				0.10

Sources

1. EcoInvent database 3.5, released August 2018
2. Calculation of impact of recycling based on the impact of the recycling process and substitution of virgin material in column P, the allocation factor A in column N, and the downcycle factor Q in column O.
3. Calculation of impact of recycled content based on the impact of virgin material in column B, the impact of the recycling process and substitution of virgin material in column P, the allocation factor A in column N, and the downcycle factor Q in column O.
4. Average Dutch waste scenario based on the 2018 recycling statistics of the Afvalfonds Verpakkingen.
5. Use of industry averages of recycled content are already taken into account in the material, or data is unavailable.
6. Extrapolation of data from similar materials and processes from (1.)
7. Assumption/extrapolation by Partners for innovation based on data from (1.) and sources in the glass industry.
8. Calculation of CO2 impact of cleaning proces based on average water, detergent, and energy used with LCI data from (1.). Average consumptions based on literature review by Partners for Innovation and Universiteit Utrecht.
9. Calculated impact of softwood per kg based on LCI data from (1.) and the assumption that the wood has a density of 450 kg/m3.
10. Calculation based on values from Chen & Patel (2012) + transport from Brasil to Europe. Does not include effects of land use change. Chen, G. Q., & Patel, M. K. (2012). Plastics derived from biological sources: present and future: a technical and environmental review. Chemical reviews, 112(4), 2082-2099.
11. Calculation and allocation of recycling impact of drop-in bioplastics based on recycling process of fossil based PE and PP. The biobased plastic is regarded as a "carbon sink" as proposed by CE Delft (2017). *Biobased Plastics in a Circular Economy.*
12. The production impact of 'Cardboard box folding' is included in the total impact of Corrugated box and Folding box under Material. The impact of sawing and drying of wood is included in the material too.
13. Default A & Q parameters as suggested by the European Commission's Joint Research Centre.
14. Assumption/extrapolation of A & Q parameters based on data from (13.).
15. Calculated impact of MDF per kg based on LCI data from (1.) and the assumption that the MDF has a density of 720 kg/m3.

Appendix F

Project brief

DESIGN FOR our future

TU Delft

IDE Master Graduation

Project team, Procedural checks and personal Project brief

This document contains the agreements made between student and supervisory team about the student's IDE Master Graduation Project. This document can also include the involvement of an external organisation, however, it does not cover any legal employment relationship that the student and the client (might) agree upon. Next to that, this document facilitates the required procedural checks. In this document:

- The student defines the team, what he/she is going to do/deliver and how that will come about.
- SSC E&SA (Shared Service Center, Education & Student Affairs) reports on the student's registration and study progress.
- IDE's Board of Examiners confirms if the student is allowed to start the Graduation Project.

USE ADOBE ACROBAT READER TO OPEN, EDIT AND SAVE THIS DOCUMENT

Download again and reopen in case you tried other software, such as Preview (Mac) or a webbrowser.

STUDENT DATA & MASTER PROGRAMME

Save this form according the format "IDE Master Graduation Project Brief_familyname_firstname_studentnumber_dd-mm-yyyy".
Complete all blue parts of the form and include the approved Project Brief in your Graduation Report as Appendix 1 !

family name: Gillissen
initials: G given name: Gijs
student number:
street & no.:
zipcode & city:
country:
phone:
email:

Your master programme (only select the options that apply to you):

IDE master(s): ★ IPD ( ) DfI ( ) SPD
2nd non-IDE master:
individual programme: - - (give date of approval)
honours programme: ( ) Honours Programme Master
specialisation / annotation: ( ) Medisign
( ) Tech. in Sustainable Design
( ) Entrepeneurship

SUPERVISORY TEAM **

Fill in the required data for the supervisory team members. Please check the instructions on the right !

** chair: R.J.H.G. van Heur dept. / section: AED
** mentor: M. Buijs dept. / section: DOS
2nd mentor:
organisation:
city: country:

comments (optional)

Chair should request the IDE Board of Examiners for approval of a non-IDE mentor, including a motivation letter and c.v..

Second mentor only applies in case the assignment is hosted by an external organisation.

Ensure a heterogeneous team. In case you wish to include two team members from the same section, please explain why.

Procedural Checks - IDE Master Graduation

TU Delft

APPROVAL PROJECT BRIEF

To be filled in by the chair of the supervisory team.

chair R.J.H.G. van Heur date 17 - 02 - 2021 signature

CHECK STUDY PROGRESS

To be filled in by the SSC E&SA (Shared Service Center, Education & Student Affairs), after approval of the project brief by the Chair.
The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total: _____ EC

Of which, taking the conditional requirements into account, can be part of the exam programme _____ EC

List of electives obtained before the third semester without approval of the BoE

YES all 1st year master courses passed

NO missing 1st year master courses are:

name _____ date - - signature _____

FORMAL APPROVAL GRADUATION PROJECT

To be filled in by the Board of Examiners of IDE TU Delft. Please check the supervisory team and study the parts of the brief marked **.
Next, please assess, (dis)approve and sign this Project Brief, by using the criteria below.

- Does the project fit within the (MSc)-programme of the student (taking into account, if described, the activities done next to the obligatory MSc specific courses)?
- Is the level of the project challenging enough for a MSc IDE graduating student?
- Is the project expected to be doable within 100 working days/20 weeks ?
- Does the composition of the supervisory team comply with the regulations and fit the assignment ?

Content: APPROVED NOT APPROVED

Procedure: APPROVED NOT APPROVED

comments

name _____ date - - signature _____

Initials & Name G Gillissen Student number 4442652

Title of Project Sustainable Packaging of Cooled Fresh Food Logistics for Goodcase.

Sustainable Packaging of Cooled Fresh Food Logistics for Goodcase.

project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date 15 - 02 - 2021 16 - 08 - 2021 end date

INTRODUCTION **

Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

About Goodcase:
Goodcase aims to inspire consumers to make more conscious decisions about their eating habits with food boxes filled with sustainable food alternatives delivered to their doorstep. We bring consumers in contact with sustainable food alternatives produced by smaller (local) companies and startups, which can often not be found in the supermarket (yet). These companies often have an interesting story to tell, which plays a key role in inspiring our consumers.

A Goodcase box does not replace your normal groceries, nor is it a mealbox (like HelloFresh). It contains separate products which can be used however the customer desires. Some products could be combined into a meal and suggestions are provided if necessary. Therefore, customers regard Goodcase as an additional monthly expense (or gift to themselves). The current boxes are sold for €35 each, including shipping.

About our Customer:
With the current trends in e-commerce it has become normal to order food online. Our customers (80) and subscribers (156) can be described as conscious, working people - mainly females - living in urban environments. Their diets vary from flexitarian, vegatarian and vegan. Their jobs and families demand a lot of time, resulting in little time to do research about sustainable food. But they do want to be more sustainable (pain). Goodcase aims to take away this pain by offering the complete package, the products and their stories, in a convenient manner.

Opportunities and Limitations:
Cooled/frozen products are estimated to be about 40% of the sustainable food market*. This category is also indicated by our customers to be most inspiring, as concluded from the 3 pilots executed by Goodcase (total of 97 sales and 15 different suppliers). Therefore, Goodcase decided it is inevitable to exclude them from our boxes.

On the other hand, cooled products increase complexity with logistics. Products need to stay cooled (< 4 Celcius) during the whole logistic process (Transport: Fridge > Goodcase box > Distribution center > Out for delivery > Customer). Cooled transport is an option, but it remains an expensive one and unnecessarily cooling every product in the box is a waste of energy. In addition, other options open up with current trends in logistics such as same day delivery. Only cooling the right products from inside the box could be a feasible, cheap and more sustainable option.

Current solution:
Currently, a cardboard box is used to transport all the products. A recycled cooling pack and insulation material are added to the box to cool the products from the inside. However, this does not guarantee the best product quality when the box arrives at the customer, it takes a lot of space and requires a lot of tape to work properly. Besides that, some customers complain about the use of a lot of one-time use material. Goodcase aims to inspire their customers: the whole experience should be high standard. With the current solution this standard can not be guaranteed. Therefore, a more reliable and efficient solution is required.

* estimation based on interviews with experts and suppliers over the past half year.

space available for images / figures on next page

introduction (continued): space for images

image / figure 1: Box delivered at customer (Pilot 1), box emoji added for privacy reasons.

image / figure 2: Selection of products in Pilot 3 (January 2021)

PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

The existing cooling solutions to keep our foods fresh during transportation do not meet the standard our customer (and Goodcase) desires. With all members of Goodcase we discussed and agreed to focus on a solution which cools from the inside the box.

In order to create a seamless customer experience three problem areas are focused on:
1. OPTIMIZING PERFORMANCE
Reliably and efficiently keep the products cooled during transportation (optimizing thermodynamics, materials and ergonomics for fulfillment)

2. SUSTAINABILITY
Make the solution more environmentally friendly compared to alternatives (Source sustainable materials which are recyclable / compostable and allow for responsible production methods)

3. COST
Make the solution fit with the margins of current boxes(keeping the price comparable to other solutions in the market)

Besides that, ergonomics, aesthetics and product experience are considered.
Re-use is left out of scope for this assignment. Properly researching the optimal logistic model, finding a business model fit, and other aspects of re-usability are expected to take too much time to work this out properly.
In addition, this problem is solved for Goodcase. Therefore, the feasibility, desirability and viability for Goodcase needs to be regarded as much as possible. While the main goal is to graduate.

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

A low environmental impact cooling solution which efficiently and reliably keeps fresh food products at the right temperature during transportation. This solution cools from the inside of the box, should be easily recyclable or compostable and should have a price comparable to current alternatives.

First, research (literature and expert interviews) is executed to map its context, analyze the parameters of performance and find potential materials. Based on the previous, design challenges and the list of requirements are created.
These are subsequently implemented in the development of concepts, which are tested in quick iterations based on a parametric model and physical testing.
The best concept will be chosen and will be further detailed and optimized for production and usability.

The expected deliverable at the end of the graduation project will be a physical product which is validated with user testing.
- The solution performs as intended: it will keep fresh products cooled (<4C) for at least 24 hours.
- The prototype is manufactured with the intended materials.
- User testing done with first batch production of 25 units.
- Improved the design based on user validation (25+ users) on desirability + feasibility based on first batch production

This product is accompanied with an implementation plan for production and costs for the time after graduation.

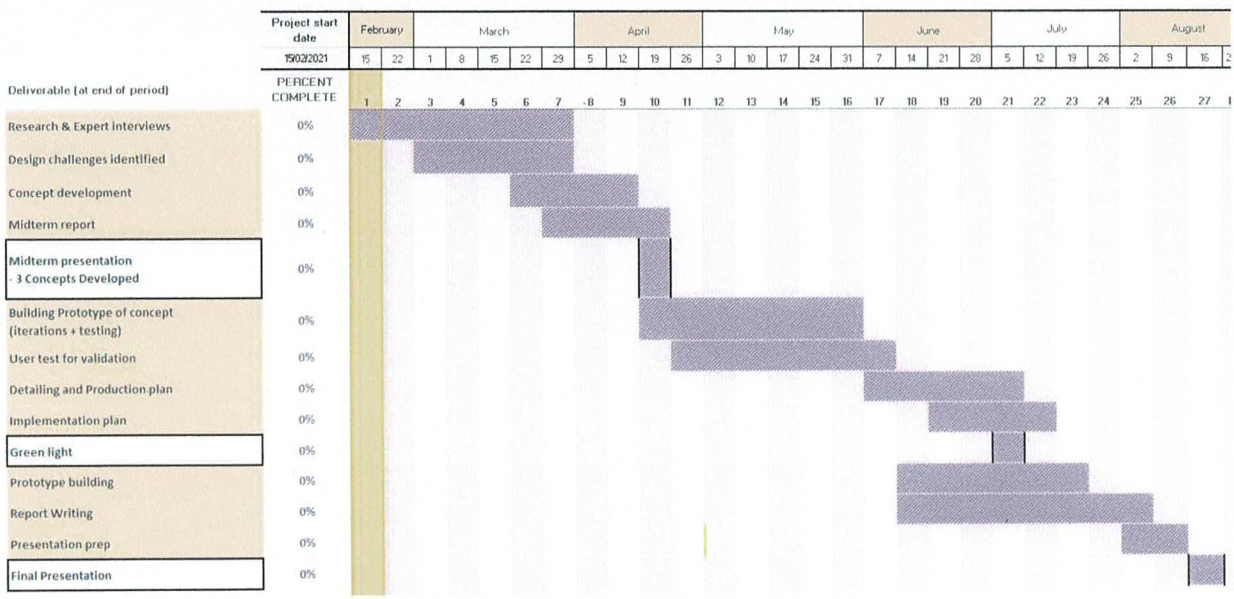
Initials & Name G Gillissen Student number 4442652

Title of Project Sustainable Packaging of Cooled Fresh Food Logistics for Goodcase.

PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 15 - 2 - 2021 16 - 8 - 2021 end date



I plan to be working 4 days per week on my graduation. The other day I will use to work on Goodcase. Therefore, graduating takes 25 weeks instead of 20. This will eventually become 26 weeks, because of the holidays during the course of this project.

Initials & Name G Gillissen Student number 4442652

Title of Project Sustainable Packaging of Cooled Fresh Food Logistics for Goodcase.

MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

I am interested in entrepreneurship. This has originated from my 2 years (full-time) working experience in a Delft based startup. There I started to discover what entrepreneurship is about. Ever since, I have been focused on this, even besides my studies in various projects. This is the reason why I have chosen for entrepreneurial focused electives, like Build Your Startup (BYS).

During BYS we developed our startup. I am proud of the progress Goodcase has already made, I am excited and curious to see what it could become in the future. I regard Goodcase as one big learning experience. With every step I will try to absorb as much information as possible in order to improve my own skills.

With this assignment I want to connect an IPD research to the practical business side. I hope to develop in depth knowledge in the field of sustainability and materials and make decisions based on business data/arguments. Besides, I want to gain more practical experience in the field of talking with suppliers, experts, negotiations, production companies etc.

I strongly believe you should never stop learning, especially as an entrepreneur. Therefore I try to absorb and reflect as much as possible. The overarching goal is to not develop myself as an entrepreneur but also as a person. Continuously stepping out of my comfort zone will the key to do so. I would like my supervisory team to challenge me to do so during my graduation project. I am looking forward to start!

FINAL COMMENTS

In case your project brief needs final comments, please add any information you think is relevant.

I plan to be working 4 days per week on my graduation. The other day I will use to work on Goodcase. Therefore, graduating takes 25 weeks instead of 20. This will eventually become 26 weeks, because of the holidays during the course of this project.

Initials & Name G Gillissen Student number 4442652

Title of Project Sustainable Packaging of Cooled Fresh Food Logistics for Goodcase.

Appendix G

Correspondence and interviews with logistic parties and experts

!?

Interviews Logistics Parties

Ayelet Karo, Accountmanager, Fietskoeriers

Name	Insights
25-05-2021	
Doen jullie ook reverse logistics	nog niet, collega wel
Kosten gestaffeld brievenbus	
Kosten gestaffeld compact pakket	
Untitled	lucas l.hullegie@cycloon.eu
Untitled	

Rein Hofhuis, Sales & Capacity manager, Red je Pakketje

Name	Insights
23-03-2021	
Hoe zien jullie de toekomst van logistiek in Nederland? Wat gaat er veranderen en waar komt dat door?	De markt is enorm snel aan het veranderen, de snelheid van verandering neemt ook exponentieel toe. Komen veel nieuwe spelers bij, vooral diepe zakken geven de doorslag om marktaandeel op te eisen. Extreme focus op de consumetn, en hoge stopdichtheid creeren dmv dichtheidsmodellen. Maar kostprijs blijft hoog →bijvoorbeeld 3x zo veel volume kan resulteren in een stopdichtheid van maar 30% omhoog. Budbee, in zweden biedt elke webshop (bijna) alle vervoerders aan (soms wel 8-10) keuze is voor consument, webshop is hierbij onafhankelijk in proces. Huidige gebruik van volumecontracten van postnl kan juist blokkade vormen om consument in NL te laten kiezen. RJP doet niet aan volumecontracten.
Hoe gaat red je pakketje de komende 1-5 jaar veranderen? Wat zijn de grootste uitdagingen?	Het doel is om de **eerste volledig elektrische pakketdienst** te worden die een heel land bedient. Binnen nu en 1 jaar volledig elektrisch.
Focus op food of normale zendingen?	Food binnen ecommerce grootste groeier. Veel food spelers leveren via **TGN (tijdgebonden netwerk van postnl)** spoed leveringen van pakketten. PostNL food veel geld erin gestoken (+/-35 mln). Huidige kostprijs voor food ligt nog steeds hoog. Rond 1000-1500 food pakketten per dag. verwacht dat alle food online gaat gebeuren, grootste partijen zullen uber model blijven proberen om marktaandeel te borgen.
Hoe zorg je voor one-time succes leveringen? Hoe zou dat beter kunnen in de toekomst?	Het is mogelijk om binnen 33 uur zending voor 2e maal aangeboden te hebben. We hebben een 98% successrate op eerste poging.

Name	Insights
Hoe ziet een levering er over 5 jaar uit? Wat is er anders en waarom?	Lastmile total cost of ownership van elektrische bus is goedkoper te krijgen. parcellshaming → groene delivery opties aanbieden wordt de norm. zelf onderzoek gedaan → veel consumenten gaven aan bereid te zijn extra te betalen voor sameday delivery, maar er is amper draagvlak om extra te betalen voor gecompenseerde levering. Laat zien hoe de consument erover denkt en hoe de consument daadwerkelijk bereid is te handelen.
Hoe ga je snelheid garanderen bij meerdere ontkoppelpunten?	Geen extra overslag. dus geen tijdsverlies
Termen	
Personen	Frans luc brouwers Cityhub f.bouwers@cityhub.nl Velove (zweedse fietsen) dries.willems@velove.se

Mieke Steenbrink, Sales, Red je Pakketje

Question	Insights
15-03-2021	redjepakketje grote bedrijven (ikea bol.com) vanavondbezorgd kleinere webshops, Geen speciale middelen om gekoeld transport te doen. ochtend inleveren bij drop-off en in de avond bezorgen. Vlees/juices gebruiken droogijs of koelpacks. Recycold. vacuum verpakt, piepschuim box. Geen retourproces. vanavondbezorgd maakt gebruik van netwerk van redjepakketje
Kun je mij door het proces heen lopen van zon levering?	website tot 23.59 morgen in huis. 9.00 gereedmaken. uploaden vanavondbezorgd. verzendlabel doos niet schuiven producten. dropoff punt. hubs tot 13.00. scan andere hub? handmatig gesorteerd. pakketten uitgesorteerd. gescand en route gesorteerd handmatig. eind middag/begin avond route met chauffeur. naar busje en scannen. tussen 17 en 22 levering. GPS stamp ivm geen handtekening corona.
Wat zijn de risico's die daarbij komen kijken? en hoe proberen jullie die te minimaliseren?	weinig mensen bij vanavondbezorgd, kwaliteit waarborgen is belangrijk. Website features veel nieuwe dingen maar weinig capaciteit. Plotwise routeplanning systeem, dat werkt goed.
Hoe zorgen jullie ervoor foute leveringen te minimaliseren? Hoe communiceren jullie de levering?	in een keer levering. adrescontrole (rjp) betaald per uur ipv per pakket. automatische email naar klanten. email dag van levering, op halfuur nauwkeurig zien wanneer bezorger komt.
Kan een product ook weer terug de koeling in geplaatst worden	Geen koeling mogelijk. in de winter hubs niet heel warm. rjp niet focussen daarop. draaien nog steeds verlies. implementeren elektrische bussen, heeft meer prioriteit.
Untitled	

Question	Insights
Wat is de reden waarom sommige klanten juist niet voor red je pakketje kiezen?	kosten. andere vervoerders druk dan naar vanavondbezorgd. Normale verzending is voldoende. snelheid vs prijs. webshops bieden verschillende levermethodes aan klanten. vlees en brood veel snelheid. borrelboxen en restaurants. lunchboxen. en bloemen. **40/60 food/nonfood**
Wat maakt jullie anders dan Trunkrs?	
Waar liggen de uitdagingen voor de logistiek van Red je pakketje?	
Wat zijn de trends op het gebied van logistiek waar jullie op in spelen?	schalen, nu nog met de hand. automatisering in sortering. kwaliteit borgen. binnen steden ander soort vervoer, zoals fietsen en drones. Fietskoerier. qua kosten opshaling belangrijk om concurrerende prijs te hebben.
Hoe ziet red je pakketje eruit over 5 jaar?	vanavondbezorgd groter binnen 20 min een dropoffpunt , RJP groeien buitenland. Co2 neutraal.
Mensen contacten (logistieke trends etc.)	Recycold.
Untitled	**Thijs van Driel**
Untitled	

Jonathan Maduro, Sales Manager, Budbee

Question	Insights
25-02-2021	
Uitleggen Goodcase en wat ik doe	hebben ze gedaan doen ze nog met willicroft. niet goed genoeg mee zijn.
Untitled	consument bepaald zelf wanneer ze langs komen systeem weet niet wat gekoeld is.
Hoe onderscheid budbee zich van andere vervoerders in Nederland? Hoe reageert de klant daarop? Voegt bezorging met budbee extra waarde toe voor de klant?	
Leveren jullie ook food? ZO ja, ook gekoelde producten?	
Welke problemen lopen jullie tegen aan?	
Stel dat wij Goodcase pakketten willen laten bezorgen, hoe gaat dat in zijn werking?	
Minimale aantallen voor verzending? Wat voor invloed heeft dat op de prijs?	
Untitled	

Question	Insights
Untitled	
Untitled	

Marijn Prijs, CEO, Returnless

Questions	Insights
24-02-2021	
Uitleggen wat ik doe	zelf hellofresh puur uit gemak. vegetarische variant. Irritatie aan doos iedere week met zakken. Waarom niet kratje teruggeven zoals bij albert heijn. deels branding? Niet de meest duurzame oplossing.
Untitled	Duurzaam koelend krat. Borg voor krat (€25) ruilsysteem. **OhMyGoods hoogwaardige kant en klare maaltijden.** ook duurzaam. verpakt in karton met icepacks. allemaal eigen transport. Budbee, heel klantgericht. Trunkrs en redjepakketje.
wat doet returnless, wat maakt jullie zo bijzonder?	Klanten zijn webwinkels. Online retourproces faciliteren. Afstemmen met budbee om krat om te ruilen. geven en halen het terug.
Levering van gekoelde producten	
Duurzaamheid	
Prijs van een retourpakketje	zelf niet scherpe prijs. als je volume draait €4.40 voor retourzending. kosten voor komen ophalen of wegbrengen. 10-30 euro voorrijkosten. heen zending €4.50
Problemen?	afmetingen en veranderende voorwaardes van vervoerders. Leverbetrouwbaarheid van vervoerder. vervoerder pakketpunt en terug.
Untitled	
Contact bij budbee	
Untitled	zweeds bedrijf nu in nederland aan het uitrollen
Untitled	Plugin downloaden, als klant besteld. ga kijken naar **customer subscription model.** dan hoef je niet met returnless te werken. Altijd werken met Borg,
Untitled	**Kijk eens naar ecurring (mollie)**
Untitled	maak het heel makkelijk, kennismaken en verrassen. Gemak is belangrijk. samenhang creeeren.
Untitled	

Karlijn Pennarts, Product Owner, PostNL Food

Questions	Insights
24-02-2021	
Uitleg Goodcase → doel afstuderen → meer te weten komen over duurzaam gekoeld transport	4 jaar bij food. aparte tak binenn postnl. productontwikkeling.

Questions	Insights
Untitled	
Kun je mij meenemen door het proces van levering van gekoelde producten?	**chauffeur gaat heel anders met pakket om.**
Jullie leveren zonder gekoelde auto's ? Wat is de reden dat jullie dat niet doen?	inhoud afgeven en koelbox meenemen. als iemand niet thuis is dan bellen. kan normaal niet.
Daan → veel onderzoek naar duurzame verpakkingen, en levermethoden wat hebben jullie onderzocht? hoe passen jullie daarop aan? Zou je die onderzoeken kunnen delen?	veel onderzoek. **duurzaamheid met passieve koeling is beter dan actieve koeling**. dozen voor single use met coolpacks. nu met herbruikbare koelbox. onder aan de streep veel duurzamer en kosten efficienter. Ook diepvries met droogijs. **logistieke model is grote kostenpost.** tarief rond de €12. meest geschikt in de avond met food bezorgen.
Wat zijn de toekomstplannen voor PostNL Food? Kun je dat uitleggen	uitstootvrije lastmile
Claim hergebruiken de koelbox, wel zo duurzaam. Hoe hebben jullie onderzocht of dat daadwerkelijk duurzamer is? Hoe lang gaat de koelbox gemiddeld mee? Wat gebeurt er na die tijd?	**EPP**, tijdens ontwikkeling redelijk duurzaam qua slijtage en isolatie. gaat echt jaren mee. **diepvries 12uur goed halen soms tot 18 uur. koel 48uur of langer. korte keten.**
Hebben jullie ook tests gedaan met een herbruikbare koelbox die de klant zelf kan terugsturen? of een single use koelbox? → Wat zijn de bevindingen? → Waarom niet?	single use en reuse gebruikt. en getest. geisoleerde kartonnen dozen. best wel duur. duurder dan 12 euro.
Wat zijn de grote uitdagingen op het gebied van duurzaam gekoeld transport?	tevreden over keten met koelboxen duurzaamheid. Uitstoot in last mile. In amsterdam aan het testen met elektrische voertuigen. actieradius te klein momenteel om hele traject te verduurzamen
Wat zijn de kosten voor bezorging met postnlfood als bedrijf? kleine oplage	
Wat is de hoofdreden dat bedrijven wel of niet willen bezorgen met postnl food?	niet de goedkoopste. concurrentie leen menken, lastig om gecombineerd te verzorgen. **reviva en redjepakketje trunkrs.** alleen B2C. wel om de kwaliteit en volle focus op food, unieke benadering. prijs wel vaak de reden om neit mee te doen.
Welke certificaten of regulations zijn belangrijk om aan te voldoen?	hccp (nu andere naam TLN DECRA) voedselveiligheid ISO kwaliteit veiligheid mens en miliue
Welke bedrijven zouden voor mij interessant zijn om te contacten?	denkt erover na. **Budbee (concurrent)** Redjepakketje (veel geld opgehaald voor duurzaamheid)
Heb je nog tips voor mij?	
Untitled	onderzoeken gaat ze delen.
Interesting Terms	
Untitled	

Appendix H

Logistic carrier comparison

List of carriers

Name	Type	Column	Price	MOQ / Week	Food	Sustainable	Delivery range	Website	Contact	Phone	Email
Vanavondbezorgd	Delivery	Next day Same day	€7.23	1	☑		Netherlands				
Red je pakketje	Delivery	Next day Same day	€8.95	1	☑	CO2 Neutral	Netherlands				
Trunkrs	Delivery	Next day Same day	€7.70	100	☑		Netherlands				
PostNL FOOD	Delivery Returns	Next day Same day	€12.00		☑		Netherlands				
Fietskoeriers	Delivery	Next day		10	☐	Zero Emission	Netherlands				
DHL	Delivery Returns	Next day			☐	CO2 Neutral	Netherlands				
Budbee	Delivery Returns	Next day Same day			☐	CO2 Neutral	Netherlands	https://budbee.com/	Jonathan Maduro		
Hubbel	Delivery Returns	Next day Same day			☑	Zero Emission	The Hague Area		Rinse van der Woude		
DPD FRESH	Delivery Returns	Next day			☑		Belgium				

Appendix I

Correspondence and interviews with packaging companies and experts

!?

Interviews Packaging Experts

Shen Liu #3, FarmHouse international

Aa Name	Insights
08-06-2021	
Value flow	since 90% of our customers buy it as a present, returning the packaging will be less likely.
What reward to consumer	Needs to be high enough for them to return it. Tap into current behaviour. Reward can not increase the sales price. An ecosystem with different suppliers would work better. Earn credits.
What reward to supplier	Discount
Communication incentive	
Key features to switch to reusable	1. **costs:** keep transport + packaging under €10. transport now is €8.26 **2. Food safety** Needs to be properly cleaned when in direct contact with food → **initial focus on packaged food**
market insights	AGF margins are small (4-8%) but volumes are large.
Tips	Needs to fit on pallet sizes (Europallet & blockpallet) 60 x 40 40 x 30 30 x 20
Requirements from fulfillment perspective	handles to lift the box Stackable Fit on Pallet Durable materials Inserts to fill voids
Final comments	Come present for the director → he will be interested

Annette Poiesz, The chain never stops

Aa Questions	Insights
22-04-2021	
Notes	ontvangstunit bij consumenten neerzetten. Gekoeld of bevroren. verschilt erg per product. verschillende verladers in 1 box, die geven marges aan. Vers zit de marge op. Datasouvereiniteit. Bezorger niet voor een dichte deur.
Shen → Test met koelboxen voor Hoogvliet. Hoe is dat ontstaan?	Box gaat niet door de keten. Supply chain is op standaard maten ingericht. Totes, kratten . Je zet niet zomaar een nieuwe standaard. Faciliteren derden in het proces. Ontvangstzekerheid en afleverzekerheid.
Uiteindelijke doel	Last mile efficienter en goedkoper maken. grotere marges in levertijden.
Inzichten, en grote verbeterpunten	Tom burgers, koel opleggers en ambiente opleggers.

Questions	Insights
Ontwikkelen jullie de koelbox zelf?	
Andere partijen betrokken?	Verladers en
Hoe kunnen wij elkaar helpen?	
Untitled	Wel de data verzamelen
Contacten	
Termen	
Untitled	

Tristan Algera, Co-Founder, Pack Back

Questions	Insights
15-04-2021	
Notes	Vriendin heeft food startup.
Hoe zorg je ervoor de consument het terug stuurt?	sterk afhankelijk van publiek en product. Vooraf statiegeld. Combinatie van financieel, sociale druk, data speelt een belangrijke rol. Wel opsparen en retourtermijn (1 uur tot 2 weken). Pickup wordt het opgehaald. veel liever drop-off. mensen willen controle hebben.
Veel onderzoek / tests gedaan?	Composteerbaar werkt niet altijd. Hergebruik beland. met restaurants testen. 4 basis principes 1. geschikt voor hergebruik 2. tracking om verpakking te volgen 3. Transport terug krijgen 4. Wasfaciliteit Je kan niet alles tegelijk doen. Zelf onderdeel worden → netwerk idee. verpakkingsproducenten in staat stellen om te laten circuleren. Omoda herbruikbare verpakking samen met paardekooper. Postnl gesprek gehad. Vergelijking LCA hergebruik is in hun geval niet duurzamer. nu weer contact opgenomen. Schaal gaat belangrijk worden om het betaalbaar te krijgen. Samenwerken is noodzakelijk. Bijna 3 jaar actief, 1 jaar operationeel. Het wordt een serieus alternatief. Wegwerp gaat verdwijnen: of hergebruik of hybride vorm. tax op single use. Nog wel erg niche keuze optie. Verplichte optie werkte opvallend goed.
Welke partijen zijn erbij betrokken	Rotterdam Utrecht België aantal steden en Breda en Den Haag. citymanager spelen belangrijke rol door franchise model.
Zelf onderhoud uitvoeren?	doen ze nog zelf. samenwerken met citymanagers (ondernemers). Closed loop zaken die zelf reiniging verzorgen. tracking bakje met QR code. restaurant scant bakje als hij weg gaat.
Waar ligt voor jullie de uitdaging komende jaren?	returnrate 65% of 95% verschilt erg per restaurant. Cateraar die closed loop is 100%. met vaste abonnementen is kans groot dat de returnrate hoog gaat zijn. veel controle over de keten. Uitdaging: Systeem niveau van macdonalds aankunnen. Om echt impact te kunnen maken. Genoeg drop-off locaties hebben

Questions	Insights
Hoe zit het met kosten tov gebruikelijke verpakkingen?	verdienen aann partijen die systeem afnemen. vaste fee. citymanagers dragen winst af voor gebruik systeem. verpakking is geen verdienmodel.
Hoe schaalbaar is dit model? Wat zou er moeten veranderen of beter kunnen?	Food delivery markt is groot genoeg voor komende 10 jaar. Veel meer toepassingen dan maaltijden en dranken. Veel positieve reacties.
Untitled	
Contacten	verpakkingsbedrijven: The better future factory (IO'ers) Falafval: 0649987367 (Ajuk Bakia)
Termen	
Untitled	

Shen Liu #2, Farmhouse

Questions	Insights
13-04-2021	Eu single use plastics verbannen. Logistieke systemen Loop, Pieter Pot, Hoe kan ik dat in de nabije toekomst implementeren? Toekomst visie. Zelf willen ze praktische kant onderzoeken .Bedrijf kwam langs Chainneverstops. Werken samen met de hoogvliet. Logistieke dienstverlener kan pakketten erin doen. Data getracked door consument. Upscalen. Raakvlakken. Dozen in gekoelde vrachtwagens. Door koelboxen blijft het gekoeld. Logistiek regelt koelingsproces. Passieve koeling zij als eerste klant.
Uitleg richting	
Wat is er allemaal veranderd met de overgang naar farmhouse? B2C of B2B	Keten verkorten. Bestaande loopsystemen. Goed communiceren. kennis delen met de consumenten. Bestaande systemen gebruiken.
Logistieke model uitdaging in circulaire economie	

Questions	Insights
Reverse logistics: hoe zou dat er voor jullie in een ideaal geval uitzien?	
Hoe zit het met de kosten?	
Materialen: Uitdaging verwerking	
Natuurlijke isolatoren	
Interesse in data inzichten van verzending?	
Volumes van verzending?	
Untitled	
Termen	
Contacten	Annette poiesz
Untitled	Abc logistics B2B, Chain never stops, Loop

Barbera Keukens

Questions	Insights
10-03-2021	
Ellen McArthur Foundation	Plastic economy → linear to circular
Hoe wordt je begrepen bij de consument? Welke uitdagingen liggen er op dit gebied?	Vertel het verhaal, net als met je producten. Kijk daarmee of je gaat voor herkenbaarheid (direct vergelijkbaar met bestaand product of gaat voor disruptive veranderingen)
Belangrijke beslissing	Waar in de keten ben je duurzamer
Huidige oplossing	al redelijk duurzaam, lijkt op enveloppen.
Materialen	Mycelium is erg interessant en heeft een mooi verhaal → sympathieker Karton ook goede isolator en goed recyclebaar → verhaal is minder spraakmakend
Project uitdagingen	
Technische uitvoering	Hoe zorg je ervoor dat het daadwerkelijk werkt
Consumenten overtuiging	Hoe neem je de consument mee in het verhaal en de impact van het product?

Aa Questions	Insights
Untitled	
Contacten	
Elvin Karana	Professor in materials TU Delft
Theo van de Pol	Unilever (voormalig?) disruptive innovation manager ervaring met gekoeld en isolatie
Herwin Wichers	Smurfit Kappa , sales director. open minded en veel kennis.

Shen Liu, Innovation manager, YEX

Aa Questions	Insights
17-02-2021	
Achtergrond? TU Delft?	Yes, Industrial Design Engineering
Wat doet YEX? B2B?	Mainly B2B, Now also shifting towards B2C
Verzenden jullie ook gekoelde producten? Zo ja, hoe doen jullie dat? Welke claims/garantie kan je geven?	Now fast delivery with TRUNKRS, cooling not guaranteed if consumer is not at home.
Wat maakt jullie verpakking anders t.o.v. alternatieven? Produceren jullie de verpakkingen ook zelf? Kun je mij door dat proces meenemen?	We dont produce ourselves. packaging suppliers nearby. Interested in buying our product. Cooling is around 8 degrees.
Wat zijn de toekomstplannen voor YEX? Waarom kies je voor die bepaalde richting?	More focus on B2C. With reusable cooling boxes that are sustainable. Logistic model will be more their focus.
Wat zijn de grote uitdagingen op het gebied van duurzaam verpakken?	Keeping costs down and time (to run through all the inventory) About sustainable innovation: Consumer drives the innovation → Media → Law → Companies change based on the law.
Welke bedrijven zouden voor mij interessant zijn om te contacten?	Bedrijf met isolerende papierstructuren (hij was naam vergeten) Zij kunnen groente en fruit leveren, goede contacten met productiebedrijven.
Heb je nog tips voor mij?	
Untitled	
Interesting Terms	**IFCO kratten, Meermalig fust, single pastic packed,**
Untitled	

Appendix J

List of alternative cooling products

Alternatives

What alternatives are out there?
What are their strong/weakpoints?
What improvements could be implemented?

List of available alternatives

Name	Use	Type	Recyclable	Cooling claim	Price	Company	Website
Gousto Eco Chill Box	Food Insulation	Single-use	Recyclable	1-12 12-24		Gousto (designed by Soft box systems)	https://www.foodanddrinktechnology.com/news/32926/s creates-100-recyclable-insulated-shipper-for-gousto-foo deliveries/
TempGuard	Insulation	Single-use	Recyclable Recycled	24 - 48	€0.70	Moonen (Tempguard by Sealair)	https://www.moonendirect.nl/koelelementen/pk-44-doos tempguard-s-290×800mm-100-recyclebaar https://www.sealedair.com/products/protective-packaging/insulated-box-liners#tempguard-tab
Tempex box	Insulation	Reuse	Poor Recyclability		€12.50		https://www.horecaworld.biz/thermobox-h-30-x-60-x-4(polypropyleen-zwart-gastro?gclid=CjwKCAiAmrOBBhA0EiwArn3mfG35UkQsYHVy7B_I 6JZLpWbftqpoZmd90NI7p-Xt7fzsbzxoCGtYQAvD_BwE
Recycle-air	Food Insulation Pharmaceutical	Single-use	Recyclable	24 - 48	€4.05	Hydropack	https://hydropac.co.uk/product/freshpac-recycle-air/
EnviroCool	Insulation	Single-use	Compostable Recyclable	24 - 48	€2.80	Hydropack	https://hydropac.co.uk/product/envirocool/#description
TempCell ECO	Insulation	Single-use	Recyclable	48 - 72		Softboxsystems	
Recycold	Food Insulation	Single-use	Recyclable Recycled	1-12 12-24	€3.00	Recycold	https://www.recycold.nl/webshop/Recycold-Cool-Kit-Sm Sets-p126673792
WoolCool	Food Insulation Pharmaceutical	Single-use	Compostable Recyclable Recycled	12-24 24 - 48 48 - 72	€3.00	Woolcool	https://www.woolcool.com/food/#faq
Foodmailer	Food Insulation	Single-use	Recyclable	12-24		Foodmailer	http://foodmailer.net/home-en-us/

Name	Use	Type	Recyclable	Cooling claim	Price	Company	Website
GreenCellFoam	Food Insulation Pharmaceutical	Single-use	Compostable Recyclable Recycled Soluble			GreenCellfoam	https://greencellfoam.com/
LiviriSPRINT50	Food Insulation	Reuse		12-24	€49.99	Liviri	https://liviri.com/
ThermoBox	Food Insulation Pharmaceutical	Single-use	Compostable Recyclable	1-12 12-24		Smurfit Kappa	https://www.smurfitkappa.com/products-and-services/packaging/thermobox
Shoebox cooler	Insulation	Single-use	Compostable	1-12 12-24	€10.00	Ecovative	https://www.paradisepackaging.co/store/p/cooler
Recool	Insulation	Single-use	Compostable Recyclable Recycled	1-12	€14.95	Igloo	https://www.iglookoelboxen.nl/recool-biologisch-afbreek koelbox-vernieuwd
Playmate	Insulation	Reuse	Poor Recyclability Recycled	1-12	€29.95	Playmate	https://www.iglookoelboxen.nl/playmate-mini-koelbox
Repreve Avery tote	Insulation	Reuse	Recycled	1-12	€19.99	Igloo	https://www.igloocoolers.com/collections/repreve/produ avery-tote?variant=32094077222995
CEMP Insultation	Food Insulation	Reuse	Compostable Recyclable	1-12 12-24	€3.00	WOOLCOOL	https://www.woolcool.com/cemp/cemp-insulated-liners/
Puffin Packaging	Food Insulation	Reuse	Compostable Recyclable Recycled	1-12 12-24		Puffin	https://www.puffinpackaging.co.uk/

Appendix K

Correspondence and interviews with customers of Goodcase

Interviews Customers

Naam	Date	Question 0	Question 1	Question 2	Question 4	Comments	Comments Goodcase
Untitled		**Wat vond je van de koelmethode in pilot 3? Wat heb je met de koeling gedaan?**	**Heb je wel eens gekoeld eten besteld? Kun je omschrijven hoe dat ging? Wat zou er volgens jou beter kunnen?**	**Zou je voor mij kunnen omschrijven hoe voor jou de ideale manier van gekoeld eten ontvangen eruitziet? → Levering → Handelingen → Materiaalgebruik → Afval/Hergebruik**	**Hoeveel zou je bereid zijn extra te betalen voor een herbruikbare oplossing? Kun je dat kort toelichten?**	**Heb je nog verdere vragen of opmerkingen?**	
Customer 1	@March 2, 2021	vet dat past binnen geheel plaatje. koeling herbruikbaar en recyclebaar. wat als ik meerdere dozen bestel en mijn vriezer vol ligt met koelpacks.	gekoelde vis gehaald. koelpack erbij doen ze dat bij elke vis? twijfel of dat de bedoeling was en of het terug gestuurd moest worden. extra service wordt gewaardeerd	als producten thuis krijgt en vast pakt ooh lekker fris. Handbeleving moet echt koud zijn. Dat het daarbij blijft, geen koelpack voor bij de verzameling. wil niet dat er energie materiaal verspilt wordt voor klein stukje van de reis. of direct recyclebare oplossing in huidige afvalstromen	bestel niet vaak genoeg gekoelde producten om daar iets over te zeggen. zet zo snel mogelijk in de koelkast. boodschappen van de albert heijn in geisoleerde doos. idealiter herbruikbaar, meest duurzaam maar proces moet wel goed gefixt zijn. leverancier weer ouder verpakking meenemen. of inleverpunt. potentie om te hergebruiken. Materiaal van meerdere keren terugsturen en tegenprestatie hoeft niet!	vet om verbazingsfactor van wat al bekend is ook duurzaam te doen. vergelijking leggen met huidige producten. pasta vorige box was al zoiets werkte. **Kortingsbon! werkte super goed maar niet gebruikt. Goed dat ingredienten samen gebruikt konden worden. skip wat sneller door de verhalen, voelt al iets vertrouwder. Thee en banabar wel aandachtig gelezen.**	Repack MudJeans

Naam	Date	Question 0	Question 1	Question 2	Question 4	Comments	Comments Goodcase
Customer 2	@February 25, 2021	positief verrast. ecomenu in plastic kratten kivietamine. was goed koel. kranten weggegooid.	komt goed gekoeld aan. wel plastic. hergebruik. gemaakt duurzaam materiaal	plasticvrij zo weinig mogelijk afval. verpakking vezel lost op met water.		box met ingredienten zelf huis schoonmaken. Snacks. zelf maken box. lijnzaadcrackers. goodcase binnen paar dagen op. verhalen maakt het leuk. social media strategie leuke content. constant verhaal.	sate in foil was bad
Untitled							

Appendix L

Correspondence and interviews with material experts and companies

Interviews Material Experts

Name	Tags
07-06-2021	
isolatie materiaal	
2-2.5 cm dik	
Untitled	

David Kasse, Flax & Linnen NL

Name	Insights
03-06-2021	
Plantenvezels als isolatie materiaal (Vlas / Hennep)	Totaal in nederland geproduceerd!
waar moet ik op letten tijdens selectie?	vezel moet aan eisen gebruiker voldoen.
Milieu impact van vlas?	telen, op de grond leggen. roten lijmstoffen uit de stengel verdwijnen. stengel mechanisch bewerken en vezels eruit kloppen. (slaan) Hennep, beiden geen chemische behandeling nodig. vezels bewerken om non-woven te maken. Onkruidbestreiding en ziektebestreiding met chemische middelen. heel weinig biologisch geteeld vlas. Hennep hoeft geen chemische middelen te gebruiken tijdens de teelt. Biologisch als pas het hele bedrijf biologisch is. Certificaten.
Geen toegang tot powerpoint van de meeting?	Mail!
Untitled	
Bedrijven en contacten	hempflax (Mark Reinders), enkev , isovlas (Rogier van Mensvoort)
Termen	
Untitled	
Untitled	

Herwin Wichers, Market Development Director, Smurfit Kappa

Aa Questions	Insights
16-03-2021	Crisp,
Over Goodcase	
De opdracht, zoektocht naar meerdere materialen, o.a. Karton	
Untitled	
Smurfit Kappa	vele toepassingen ook kunststof. Isolerende waarde is belangrijk. volumetrisch gewicht op bepaalde temperatuur op basis daarvan aantal koelelementen berekenen.
Isolerend karton	
Wat maakt karton een uitermate geschikte isolator?	golfkarton lucht tussen dus isoleert.
welke parameters zijn van belang voor de isolatiewaarde van karton? Golfgrootte, materiaaldikte etc.	dikte, thermobox dikke luchtlaag. lucht barrieres hexkarton. geen luchtverplaatsing. microplastics. hexacomb
Hoe lang blijft zo'n doos koel? Normale verzending	**hoe lang wil je dat het koel blijft?** meerdere lagen dikker materiaal, maar koelelement is het belangrijkst! **twee knoppen: isolerende waarde en koel element.**
Untitled	**qua dikte kan je niet winnen van EPS.** niks kan dat verslaan. De vraag is vooral hoelang wil je wat koud houden.
Waar liggen de uitdagingen voor een duurzame verpakking?	alles is mogelijk. **kosten onder controle houden is lastig. Sustainable verhaal facts and figures vs wat de consument perceived. Perceptie kan heel anders zijn. Veel uitleggen. Papier makkelijk bedrukken!**
Verwerken jullie ook afvalstromen in jullie verpakkingen? Waar liggen de uitdagingen om dat goed te doen?	80% van de doze is gemaakt van gerecyled papier. niet altijd gerecycled materiaal by direct food conctact. Circulair verhaal dus puur houden.
Wat zijn de grootste uitdagingen als je werkt met natuurlijke materialen?	niet resource efficient om in circulair verhaal toe te passen. fibres niet sterk genoeg. is het nou echt wel beter. **FSC FASC certificatie onafhankelijk door 3e partij.**
Untitled	
Regeneratief (carbon handprint)	ingewikkeld. raw materials CO2 impact. Papieren met positieve co2 afdruk. Takken → papier.
Hoe kan karton verwerkt worden in een oplossing die regeneratief is?	meer bomen neerzetten dan dat je gebruikt. **voor consumenten moeilijk te begrijpen.** werkt alleen maar als je virgin papier gebruikt. transparantie validation bodies.
Welke andere materialen zouden nog meer geschikt zijn?	pulp foam eierschalen ook paper fiber based. Kunststoffen zouden ook kunnen. Sealed air. oude spijkerbroeken.
Untitled	kurk ook niet meest sustainable.

Questions	Insights
Gebruiken we over 5-10 jaar nog steeds karton voor ecommerce paket zendingen? Wat gaat er gebeuren met herbruikbare oplossingen?	breedste gebruik ook voor fashion. Ultdaging krijg je de verpakking weer terug? 50-100 x gebruik is sustainable maar daadwerkelijk terugkrijgen is een uitdaging. wat als je 25% kwijtraakt? voedselproducten → **schoonmaken wat is daar de impact van. 75% halen is hoog, groot deel verdwijnt. Reduce reuse recycle.**
Contacten bedrijven personen	Huhtamaki , erimx (earth recycling international), TCpack,
Termen	
Opmerkingen	**Wil op de hoogte blijven. Thermobox kan hij contacten. geïnteresseerd in rapport.**

Barbera Keukens

Questions	Insights
10-03-2021	
Over Goodcase	
De opdracht	
Mijn benadering	
Untitled	Ellen McArthur foundation plastic economy
Single use	Determine where you actually are more sustainable in the process
Recyclable	Businessmodel for Cooling packs
Compostable	strive for a solution with a story, that resonates with the ideology of Goodcase.
Soluble	Technical execution and consumer aspect
Toegevoegde waarde?	Positively influence your consumer. Premium colors and sustainability tags. Just copy the associations of brands having characteristics you desire.
Untitled	
Thermal insulation	
Main challenges? What to take into account? What experiences do you have with this topic?	
Sustainable packaging	
Main challenges? What to take into account and what not? What experiences do you have with this topic? What companies and experts to approach?	
Untitled	
Producenten	
Experts	Herwin Wichers, Elvin Karana, Theo van de pol
Termen	

Appendix M

Mailing correspondence with Caroli Buitenhuis

Caroli Buitenhuis <info@greenserendipity.nl>
to me

Fri, 11 Jun, 14:57

Dutch > English Translate message

Turn off for: Dutch

Hi Gijs,

Voor de box denk ik dat in dit geval dan gerecyclede PP of PE of een combinatie daarvan het meest geschikt zou zijn, gezien de eisen die je er ook aan stelt.

POM en ABS zou ik niet kiezen. Niet qua materiaal en ook niet qua prijs. En ook omdat dat niet gerecycled wordt.

Hoop je hierbij wat geholpen te hebben.

Hartelijke groet!

Caroli

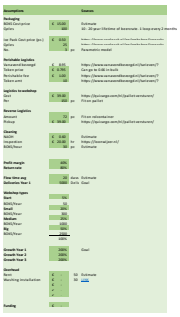
N.b. je hebt voorheen een formulier ingevuld voor de periode tot mei 2021. Er is een nieuwe periode ingegaan vanaf mei 2021. Zonder je tegenbericht ga ik er vanuit dat ik je eerder ingevulde formulier ook voor deze nieuwe periode mag gebruiken!

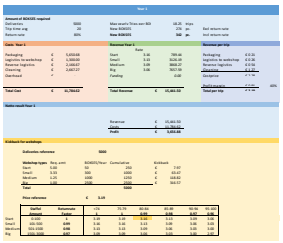
Green Serendipity

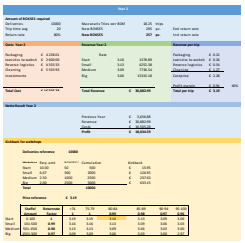
Caroli Buitenhuis, bioplastics expert for packaging & products
Visit at the Bioplastics Hub: Diemerparklaan 25, Amsterdam | Post: IJburglaan 836, 1087 EM Amsterdam
+31 (0)6 24 21 67 33 | info@greenserendipity.nl | www.greenserendipity.nl | www.biobasedpackaging.nl
Powered by ChemistryNL - Member of Renewable Carbon Initiative

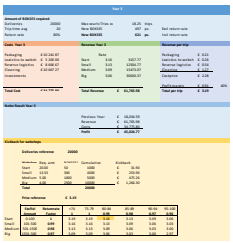
Appendix N

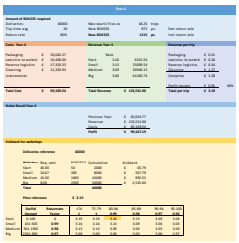
Financial model











Appendix O

Midterm presentation

Midterm Presentation

Gijs Gillissen | Goodcase | 21 april 2021

Midterm
21 april
2021

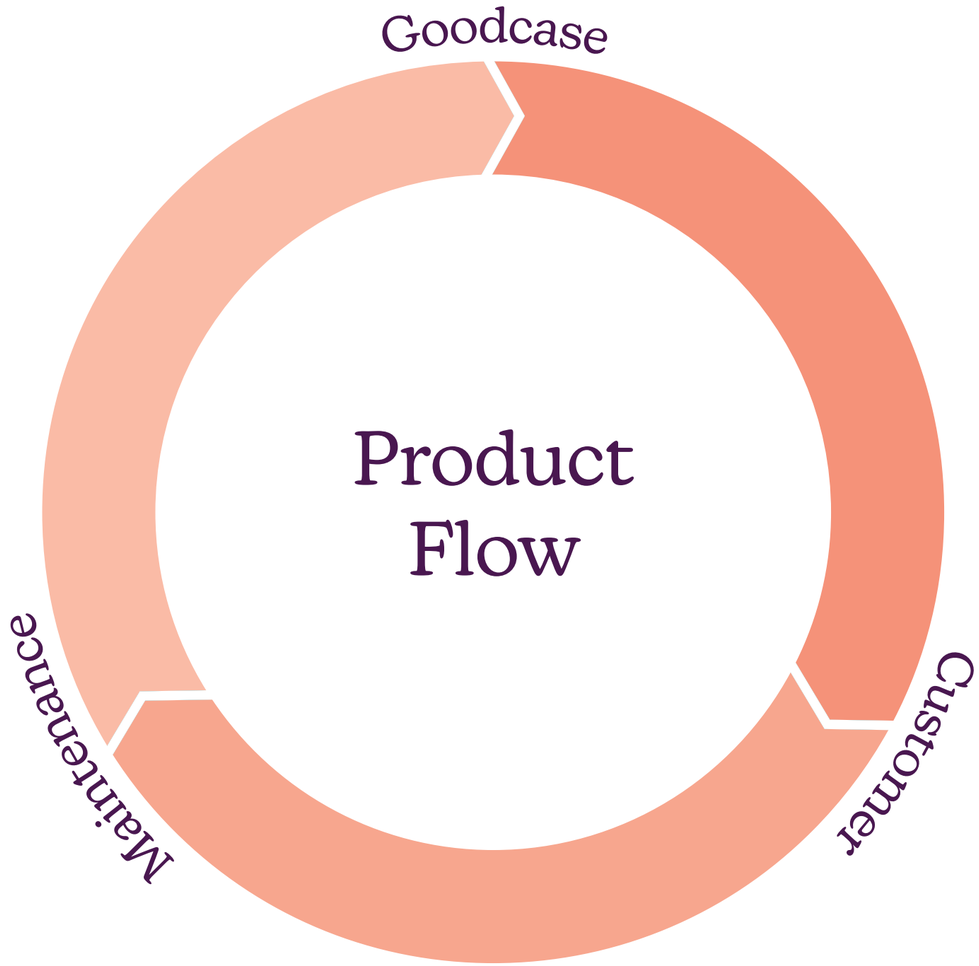
1. Circular approach
2. Design Challenges
3. Ideation
4. Proceed

Research Question

“ What is the most sustainable way of transporting cooled perishable foods for Goodcase? ”

A Circular Approach

Midterm
21 april
2021



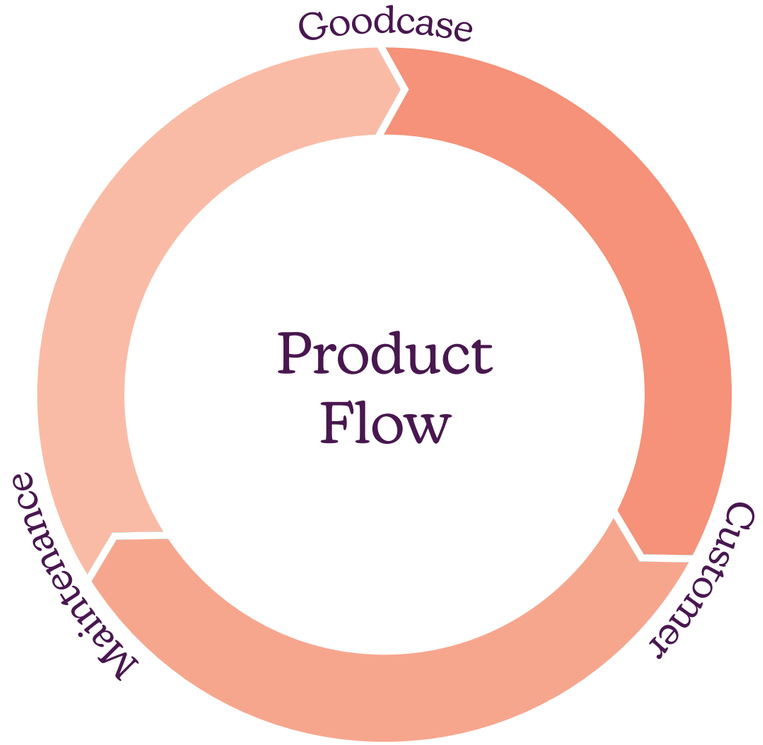
A Circular Approach

Midterm
21 april
2021

In a circular economy

Consumers become users,
Products are designed for contin-use,
Resources stay in the loop through reuse-repair-recycle.

Therefore, the product can not be designed without the system.

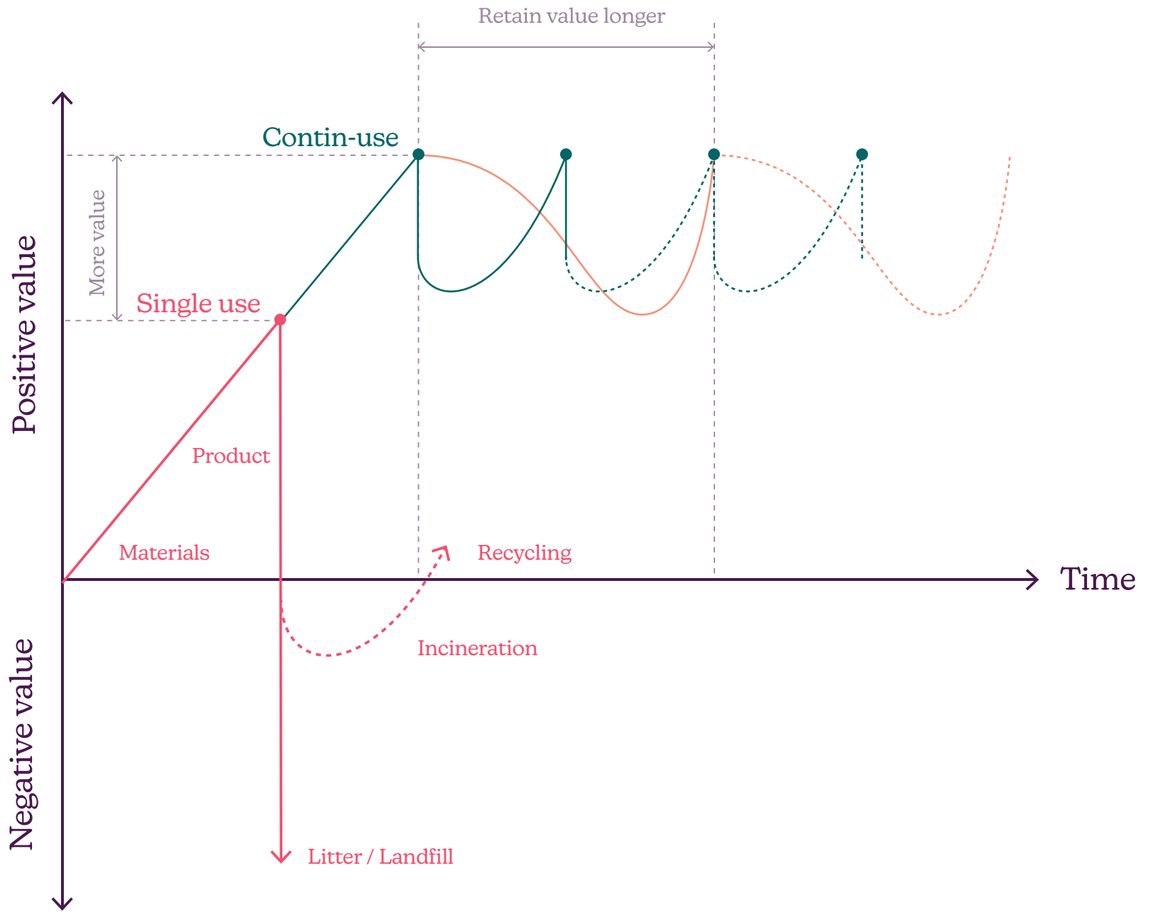


A Circular System

Midterm
21 april
2021

A circular system

Contin-use extends the product life time,
Aims to retain product value for longer,
Could add more value through material choice.



Crucial stakeholders

Midterm
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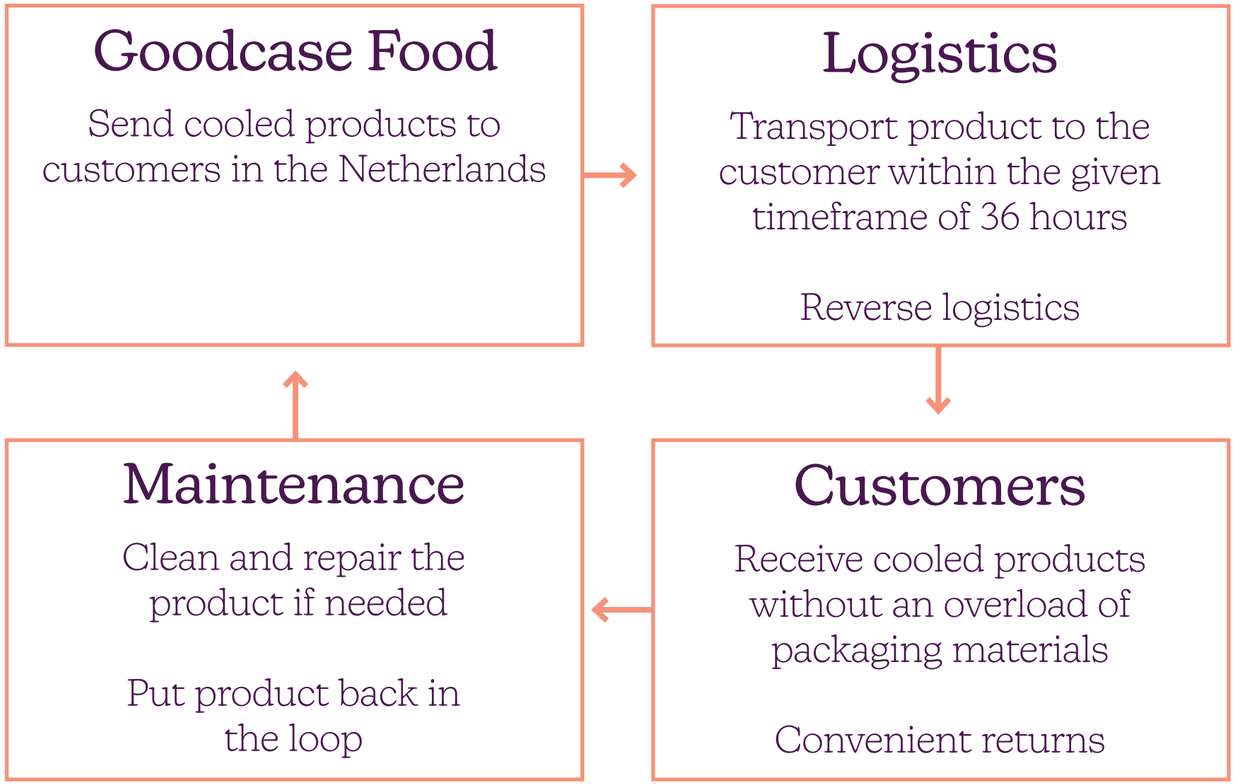
2021

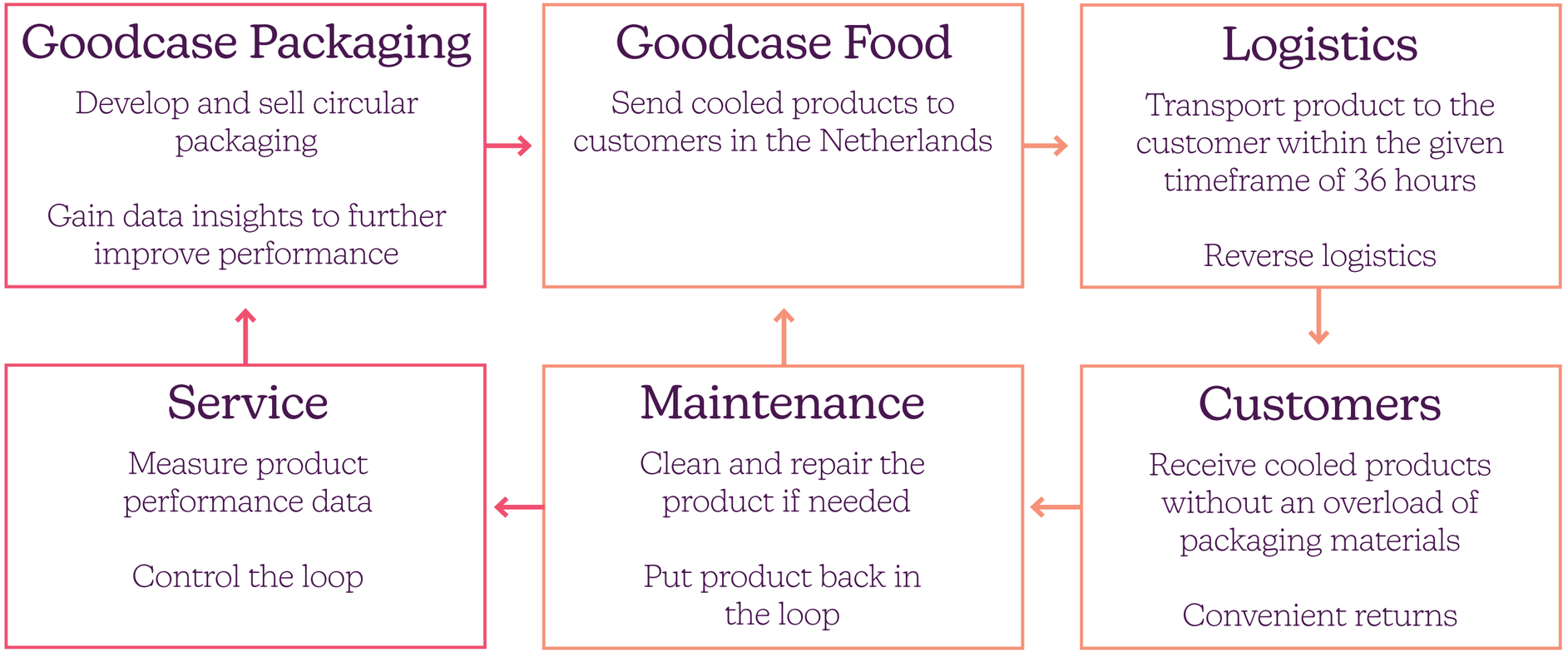


Crucial stakeholders

Midterm
21 april
2021

Data Loop

Product loop



Research Question

“ What is the most sustainable way of transporting cooled perishable foods for Goodcase? ”

Design Challenges

DC1 : Performance

Thermodynamics, Insulation principles, Context mapping, Materials

DC2 : Reuse

Circular design, Business models, Consumer experience, Materials

DC3 : Sustainability

End of Life, Materials, Production, Consumer experience

DC3 : Goodcase

Costs, Market fit, Collaborations, Production, Implementation plan

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Design Challenge 1: Performance

Optimize the passive cooling to keep perishable goods reliably within the right temperature range during transport up to the point where it arrives at the customer. Functioning is guaranteed all year around, including hot summer days.

Passive cooling is less energy intensive. A insulating barrier is used in combination with coolants in the system. The amount of coolant can be optimized per use case.

Temperature range differs per product. Keeping products under 5 C is a must. Shipping product frozen so it arrives cooled is the preferred scenario.

Transport with same day delivery logistics (e.g. red je pakketje) allows for 2nd delivery moment within 36 hours.

Functioning should be guaranteed according to standardized test protocol provided by ISTA. A typical hot summer profile is characterized by a constant temperature of 27 C.

Performance Requirements

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2021

Must have

1. The products should stay below 5 degrees for at least 36 Hours.
2. The solution should be able to function as intended within the timeframe in average temperature of 27 degrees Celsius. Conform ISTA 7E.
3. The products should be kept cool without using active energy sources.
4. The cooled volume should at least be 300x 200 x 150.
5. The volume should be as large as possible for the smallest boundary surface area.
6. The heat transfer coefficient should be kept as low as possible.
7. The specific heat capacity needs to be as low as possible.
8. The cooling compartment should be free from gaps to prevent warm air from entering the system.
9. The Thermal conductivity needs to be as low as possible.
10. Dead space in the cooling compartment should be kept minimal.

Nice to have

1. The weight of the insulation layer + coolant should be max 3 [KG]
2. The wall thickness should max X mm
3. The solution should be able to withstand X [N] pressure
4. The solution should not degrade on the shelf
5. The solution must last for at least X cycles
6. The insulation should not be affected by moisture or should be protected from moisture.

How to define the product strength for logistics? Any suggestions are welcome :)

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Design Challenge 2: Reuse

Create a reusable solution with a viable business model which creates incentive to keep the product flowing. To set up the system collaboration with other parties like maintenance and service providers needs to be explored.

Reusing lowers the environmental impact per usage and decreases the need for resource intensive recycling.

A circular business model should create value for every stakeholder. Every stakeholder should have an incentive to keep the product flowing.

Creating incentive for the consumer is increasingly important. A reward scheme is found to be necessary to guarantee a high return-rate.

Shifting towards circularity asks for collaborations. Bringing together the right parties or fitting in current streams is crucial to create impact on a larger scale.

Reuse Requirements

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2021

Must have

1. The product should be modular which makes it easy to clean, repair and refurbish.
2. The inside of the compartment should be smooth and non-porous for easy maintenance and better safety performance.
3. The cost for returning the product should be lower than €XX.
4. A fitting reward scheme should create incentive to return the package.
5. The product should be compact for efficient transport.
6. The solution should be easily collapsible for returning.

Nice to have

1. Reusing needs to be convenient, educational and purposeful.
2. Returning the solution should be fitting in current infrastructure.
3. The solution should harm the environment as little as possible.
4. The solution should be easily recyclable, compostable or soluble.

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Design Challenge 3: Sustainability

Minimize environmental impact or create positive impact over the whole lifecycle of the product. Educate and inspire consumers about environmental impact of packaging through materials, data and stories.

Construct the product with sustainably sourced or harvested materials generates more positive value in the production phase.

Closing the loop by actively monitoring the flow of resources and collaborations with conscious parties could decrease impact during usage.

Maintaining, repairing and recycling the product within the loop could decrease impact at end of life.

Educating and inspiring consumers generates awareness about the environmental impact of our packaging. This is in line with Goodcase's mission.

Actively monitoring the flow generates data that could be used to convey the messages and generate more impact.

Sustainability Requirements

Midterm
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2021

Must have

1. The solution must consist of only renewable materials.
2. The solution should harm the environment as little as possible.
3. The solution should be easily recyclable, compostable or soluble.
4. The flow of the product needs to be monitored to generate data to further improve the system.
5. The product should generate awareness about the environmental impact of our packaging.

Nice to have

1. The product should be produceable in the EU origin, preferrablymaking use of (dutch) wastestreams.
2. Data generation should be transparent for consumers to generate extra awareness.

Sustainability research and LCA could be another graduation thesis I suppose? Would be valuable just like Pieter Pot did.
Setting up the data system idem dito

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2021

Design Challenge 4: Goodcase

Optimize the solution to become an asset for Goodcase. Make it fit with the identity of Goodcase by focusing on inspiring consumers with a high quality experience. Simultaneously, the solution should be easily adaptable by other companies. Keep the cost for usage for consumers low.

A high quality consumer experience is required to make them choose reusable over single use packaging Therefore the solution should be more than just a packaging, it should be considered a product by the consumer.

The product should be easily adaptable to other companies to generate a bigger impact and to generate a higher revenue for Goodcase.

Price is a determining factor for consumers, therefore it should be competitive to current solutions from a consumer point of view.

Should this still be designed from Goodcase perspective? Or is this product steering towards a whole new company?

Consumer perspective or webshop perspective, what could be the difference?

Goodcase Requirements

Midterm
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2021

Must have

1. All materials in direct contact with food should be FDA approved
2. The cost for returning the product should be lower than €XX
3. The cost per usage should be comparable to market alternatives (avg. estimation €3.50)
4. The costprice should max be €XX

Nice to have

1. The solution should be adaptable to fit through the mailbox.
2. The product should be compact for efficient transport.
3. The cooled volume should at least be 300x 200 x 150.

Can name a price, but that would just be complete guess...

Ideation

Selected Materials

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2021

The distance between the molecules in gasses and liquids are higher compared to solids. Therefore gasses are usually better performing insulators if they are captured in a closed off volume.

Material Family	Material	Specific Heat Capacity	Thermal Conductivity	Density	Heat Transfer Coefficient
		[kJ/(kg*K)]	[W/m*K)]	[kg/m^3]	[W/(m^2•K)]
Foams	EPS	1.3	0.038	11	-
Fibers and particulates	Jute	1.2	0.25	1.44 e3	-
	Flax	1.2	0.2	1.42 e3	
	Hemp	1.2	0.2	1.47 e3	
Natural Materials (plants)	**Mycelium**	-	**0.05**	**100**	-
	Balsa Wood	1.66	0.13	240	
Natural Materials (animal)	Sheep Wool	1.35	0.2	1.28 e3	-
	Feathers	-	0.03	25	
Composites	Cornstarch	-	-	24	-
Honeycombs	Cardboard honeycomb	1.34	0.06	480	-
Gasses	**Air**	**1.0**	-	**1.27**	**25**

Morphological chart

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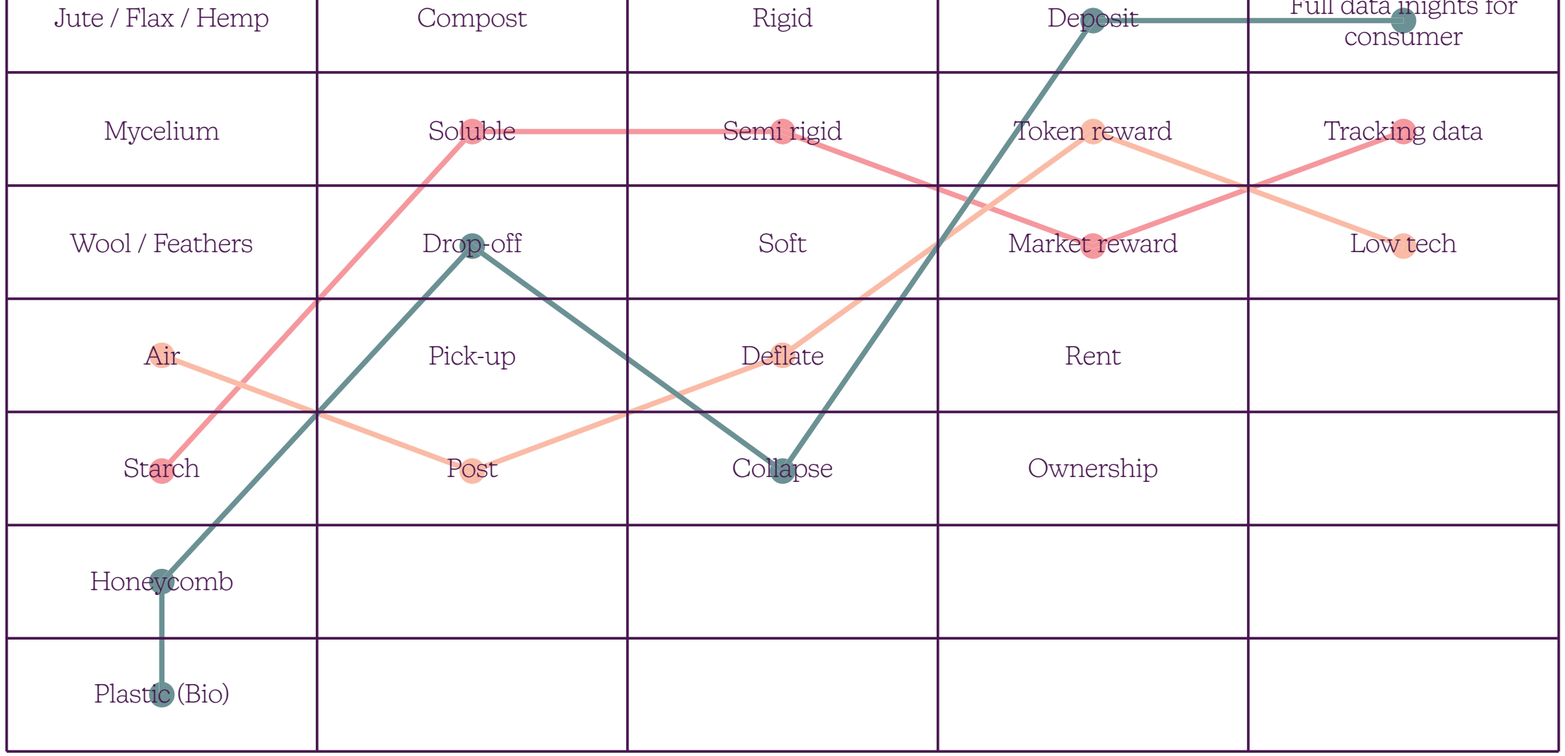
21 april
2021

Insulation type	Return method	Compact	Business model	High / Low Tech
Jute / Flax / Hemp	Compost	Rigid	Deposit	Full data inights for consumer
Mycelium	Soluble	Semi rigid	Token reward	Tracking data
Wool / Feathers	Drop-off	Soft	Market reward	Low tech
Air	Pick-up	Deflate	Rent	
Starch	Post	Collapse	Ownership	
Honeycomb				
Plastic (Bio)				



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Inflatable air insulation

Insulation type	Air
Returns	Post returns
Compact	Flexible packaging (a la RePack)
Model	Token Goodcase
High/Low tech	Low tech

Soluble insulation

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Insulation type	Corn starch
Returns	Drop-off point
Compact	Semi rigid
Model	Deposit
High/Low tech	Track and Trace

Honeycomb insulation

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21 april
2021

Insulation type	Air + Bioplastic
Returns	Drop-off point
Compact	Collapse
Model	Reward marketplace
High/Low tech	Hightech

Applying focus

Initial focus on designing a functioning product

A functioning product is believed to provide valuable insights for user tests and it could speed up attracting other parties.

Proceed

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2021

Ideation

Embodiment

Develop concepts further and Choose concept

Select Material

Parametric model

Connect parties for prototyping (small batch)

Prototyping

User tests: BBQ box

Further Improvements

Connect collaborating parties

Implementation plan

Green Light meeting

What to look out for when approaching parties?
YEX interested to partner me with production companies and speed up the process + run tests
Planning feels quite tight, how to give myself more room?

21/04/2021

07/06/2021

07/07/2021

Thanks!

Gijs Gillissen | Goodcase | 21 april 2021

Appendix P

Creative session with customers

Welkom!

Super tof dat je er bent. Vandaag ga je deelnemen aan een creatieve sessie

Samen gaan we **zo veel mogelijk ideëen genereren.**

Daarvoor heb ik een aantal opdrachten voorbereid die ons op weg gaan helpen.

Over deze sessie:
Duur: 60 min
Deelnemers: 6
Benodigdheden: Goed Humeur :)

Brainstorm?! Hoe moet dat?

Geen zorgen hier staan de belangrijkste regels op een rijtje:

- Deel wat in je op komt: Foute antwoorden bestaan niet
- Stel je oordeel uit
- Haak in op elkaars ideëen
- Hoe meer suggesties hoe beter
- Ga uit van het positieve
- Iedereen is gelijk

Opwarmen

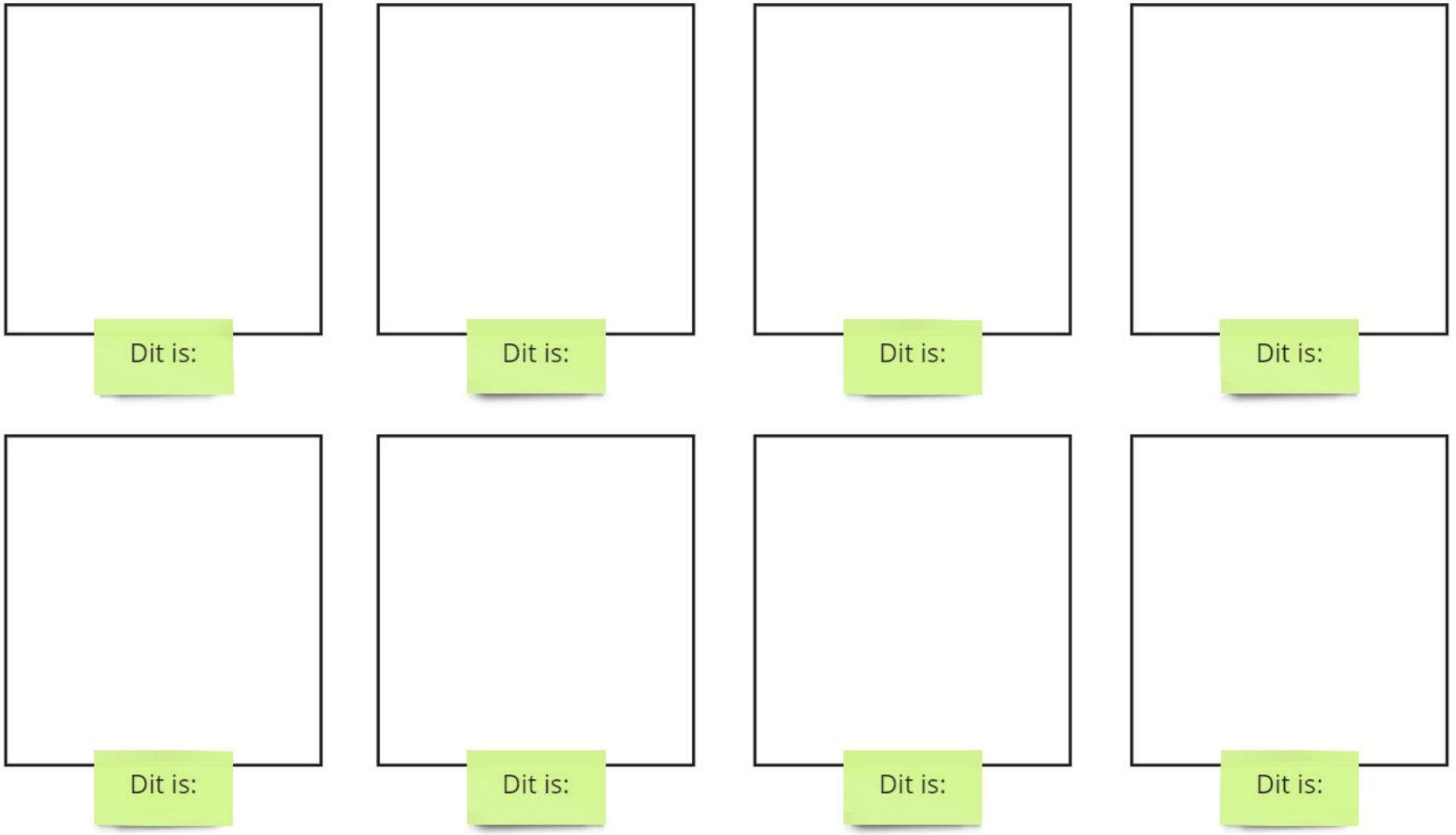
5-10 Minuten

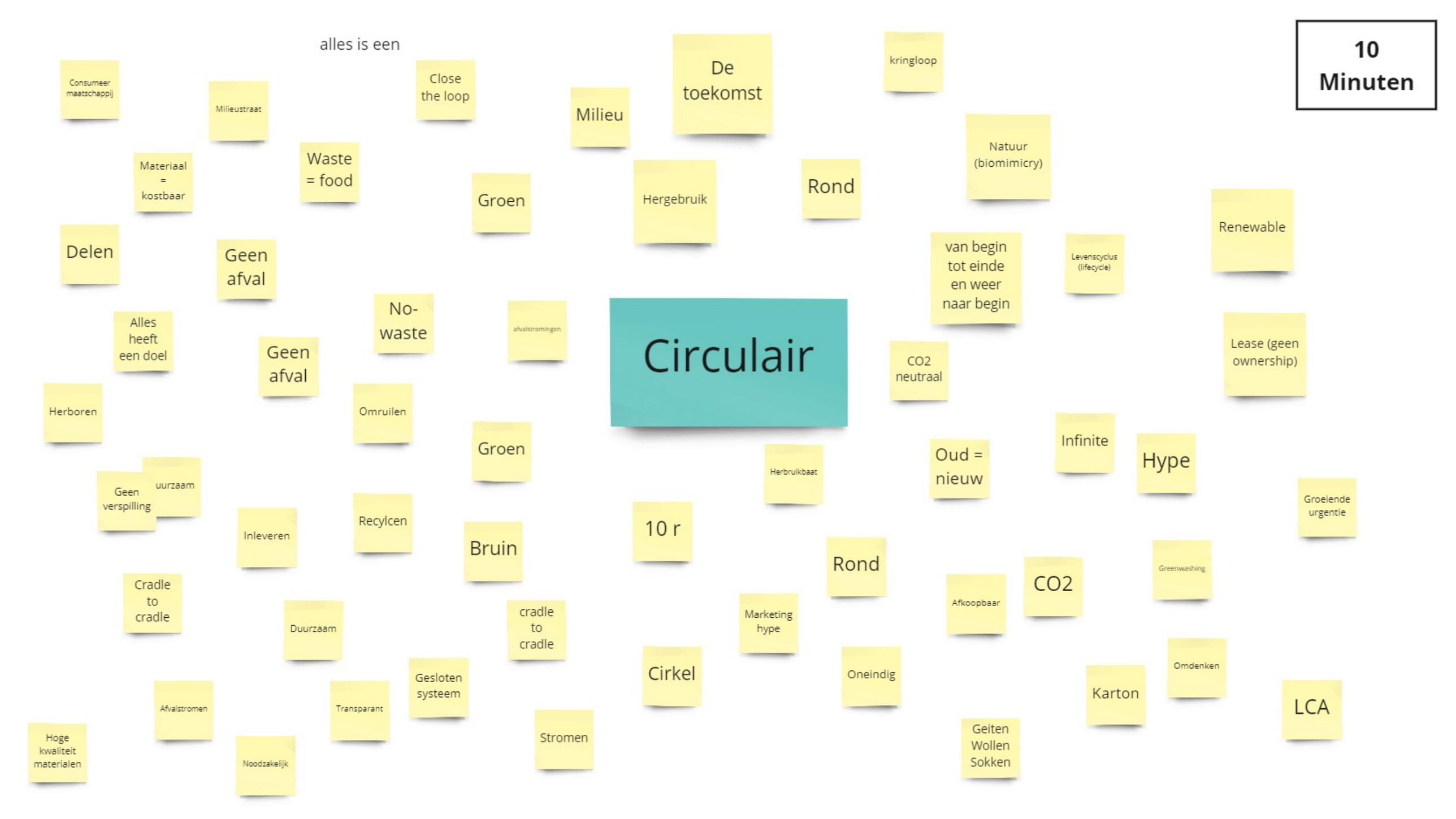
Pak iets uit je huis dat jou omschrijft

Licht kort toe

Tekenen maar!

5-10 Minuten




10 Minuten
alles is een
Consumeer maatschappij
Milieustraat
Close the loop
Milieu
De toekomst
kringloop
Materiaal = kostbaar
Waste = food
Groen
Hergebruik
Rond
Natuur (biomimicry)
Delen
Geen afval
van begin tot einde en weer naar begin
Levenscyclus (lifecycle)
Renewable
Alles heeft een doel
No-waste
afvalstromingen
Circulair
Lease (geen ownership)
Geen afval
CO2 neutraal
Herboren
Omruilen
Groen
Infinite
Hype
Herbruikbaat
Oud = nieuw
Geen verspilling
uurzaam
Groeiende urgentie
Inleveren
Recylcen
Bruin
10 r
Rond
Greenwashing
Cradle to cradle
Afkoopbaar
CO2
Duurzaam
cradle to cradle
Marketing hype
Omdenken
Gesloten systeem
Cirkel
Oneindig
Karton
Afvalstromen
Transparant
Stromen
LCA
Hoge kwaliteit materialen
Noodzakelijk
Geiten Wollen Sokken


Re-thinking
progress
ELLEN
MACARTHUR
FOUNDATION
Explaining the Circular Economy and How Society C...
YouTube

Hoe zou een circulair model voor gekoelde pakketjes eruit kunnen zien?

Beschrijf een model aan de hand van de handelingen die betrokken partijen moeten uitvoeren. Probeer zo veel mogelijk verschillende modellen te bedenken!

15 Minuten

Bron

Leverancier

Verpakkingsvrije supermarkt

Consument zorgt zelf voor verpakking

Concept

Verantwoordelijkheid bij afvalverwerker

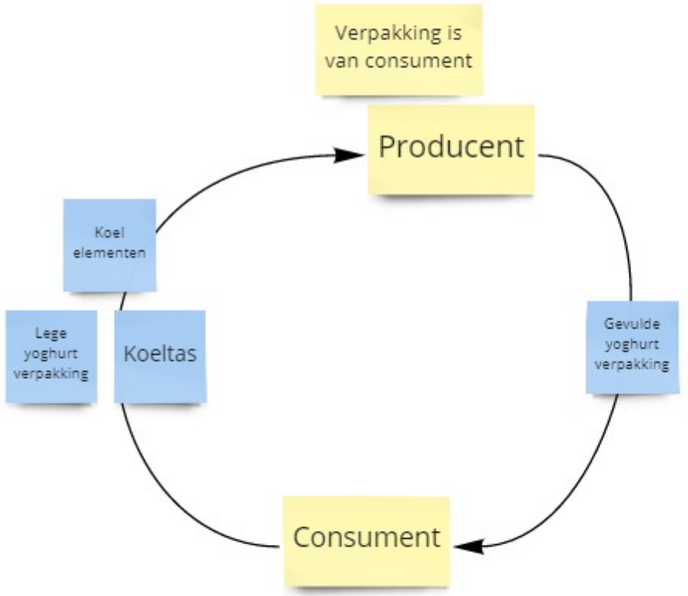
Concept

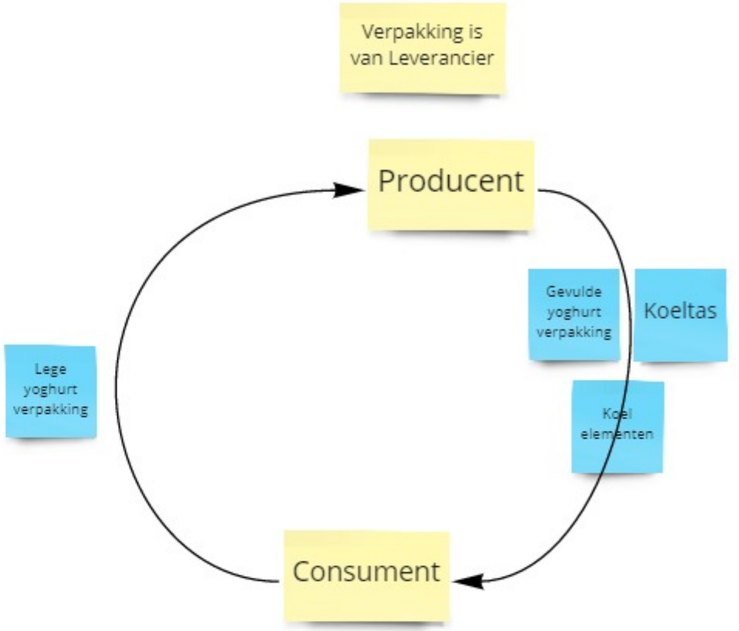
Statiegeld

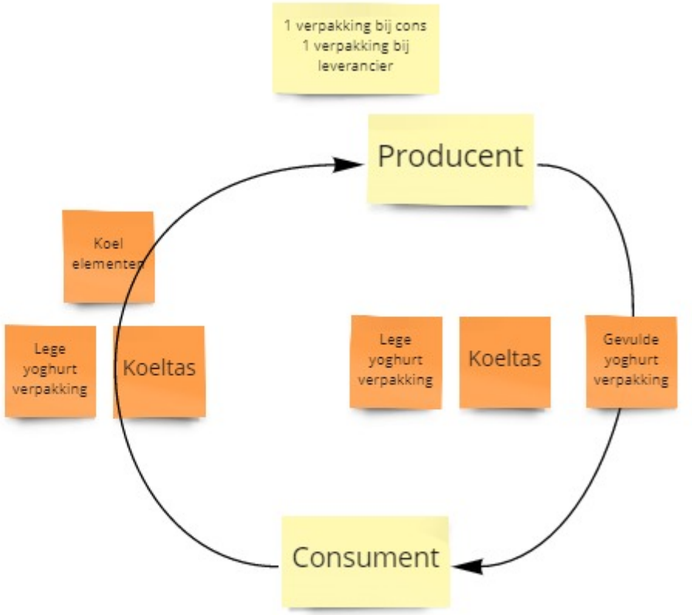
Producent blijft eigenaar van verpakking

Kratten

Potten



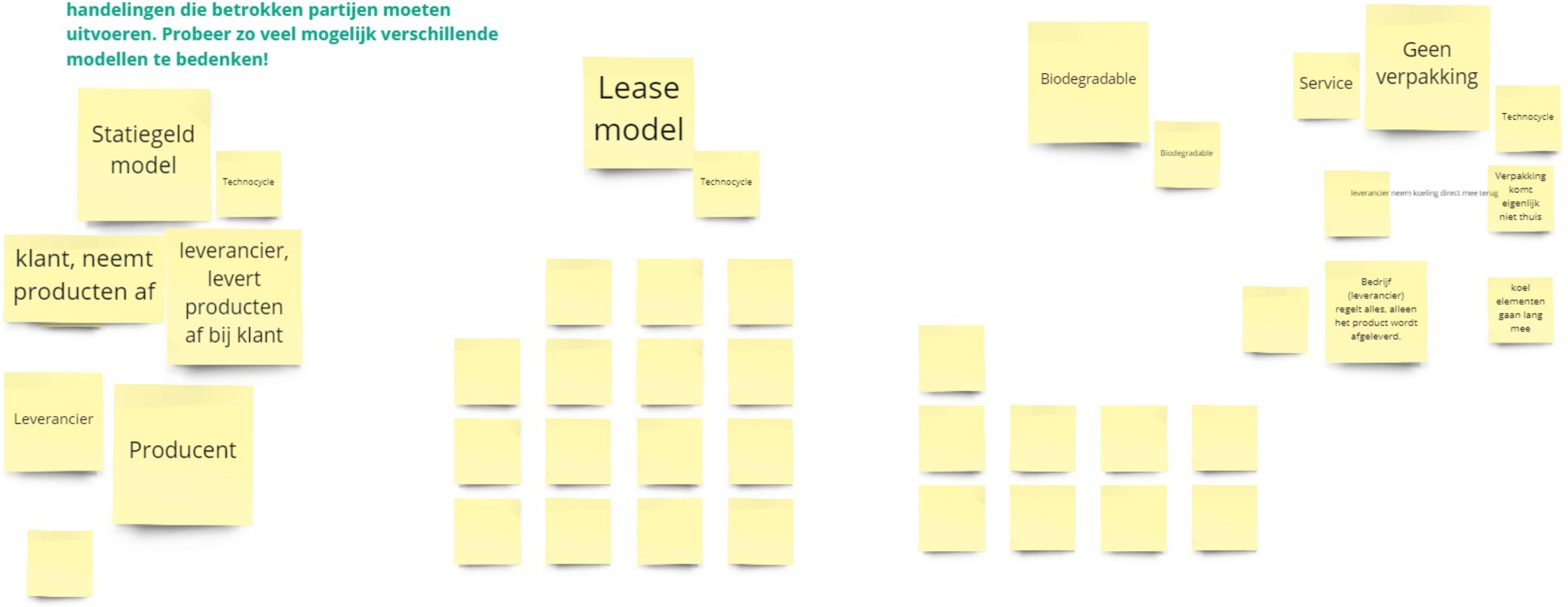




15 Minuten

Hoe zou een circulair model voor gekoelde pakketjes eruit kunnen zien?

Beschrijf een model aan de hand van de handelingen die betrokken partijen moeten uitvoeren. Probeer zo veel mogelijk verschillende modellen te bedenken!



Hoe ziet jouw ideale ervaring eruit met circulaire verpakking?

10 - 15 Minuten

Een verpakking die jouw producten gekoeld houdt tijdens transport

10 Minuten

Efficient vervoer

Bescherming

schoon houden

Het gevoel krijgen dat het 'verser' is

Zorgen dat de producten niet gaan stinken

producten vers houden

Producten langer houdbaar houden

Bescherming tegen de omgeving

Op een bepaalde temperatuur houden

Producten bundelen

Omringende pakketjes niet koud maken?

Bepaalde tijd (en afstand) overbruggen

kunnen transporteren

Welke behoefte(n) vervult het een isolerende ecommerce verpakking?

koelen

beschermen

houdbaar houden

waren bij elkaar houden

Condens resistant

product mooi presenteren

Stootvast (onvoorzichtige bezorgers)

Verzendlabel Locatie

Laag gewicht

schoon houden

recyclerbaar verpakken

herbruikbare verpakking

materiaal wat weer door de aarde opgenomen kan worden

Zie het niet als afval maar als nieuwe grondstof

Koeltas die ook op zichzelf werkt

Niet verzenden maar ophalen bij de bron door consument

Verpakking terugsturen

koelelementen teruggeven en hergebruiken

Eetbare verpakking

Verpakking is bruikbaar als iets anders

koude producten houden elkaar koud

Inleverbaar

Statiegeld

Zijn er manieren hoe die behoefte vervult kan worden zonder extra afval te creëren?

droogijs

Gemaakt van afval

Oplosbaar

Recyclebaar

Onderdeel van het product

Composteerbaar (biologisch afbreekbaar)

Hergebruiken

Lucht isoleert en is gratis!

Alleen voor vervoeren bij afleveren gelijk retour en hergebruik

Hoe vond je het gaan?

goed, wist niet wat te verwachten

Leuk. Goede intro. Vraagstukken niet heel concreet. Was soms wat aan het zoeken naar het type antwoord

Goed. Leuk om met elkaar ideeën te bespreken.

inspirerend

Leuk!

Werkt goed met miro, efficient gebruikt en leuk

voorspoedig

Wat waren je verwachtingen vooraf?

geen

Mijn verwachting was vooral mee te helpen met het zoeken naar oplossingen.

Minder gestructureerd verwacht. Goed gedaan juist!

geen

Geen idee van soort vragen maar verder wel zoals verwacht

Wat heeft je verrast tijdens deze sessie?

Leuk dat je een diverse groep aan deelnemers hebt uitgenodigd!

maakt me enthousiast om andree like minded mensen te spreken, stemt me hoopvol!!

Leuk met andere deelnemers! En discussies die ontstonden kunnen we uren doen

andere invalshoeken

Goed georganiseerd, dat hielp goed bij het brainstormen.

heeft me aan het denken gezet

Erg leuk om verschillende invalshoeken te zien, en ideeen van anderen

Dit wil ik nog kwijt

Had soms misschien wat concreter gemogen, nu werd er soms een beetje globaal gepraat over duurzaamheid (wat ook leuk is!)

Ga zo door Gijs! Ik zie wel wanneer je mijn koelkast komt vullen

Veel succes verder! Ben benieuwd welke richting van duurzaamheid je kiest

Ik word hoe dan ook terugkerende klant ;)

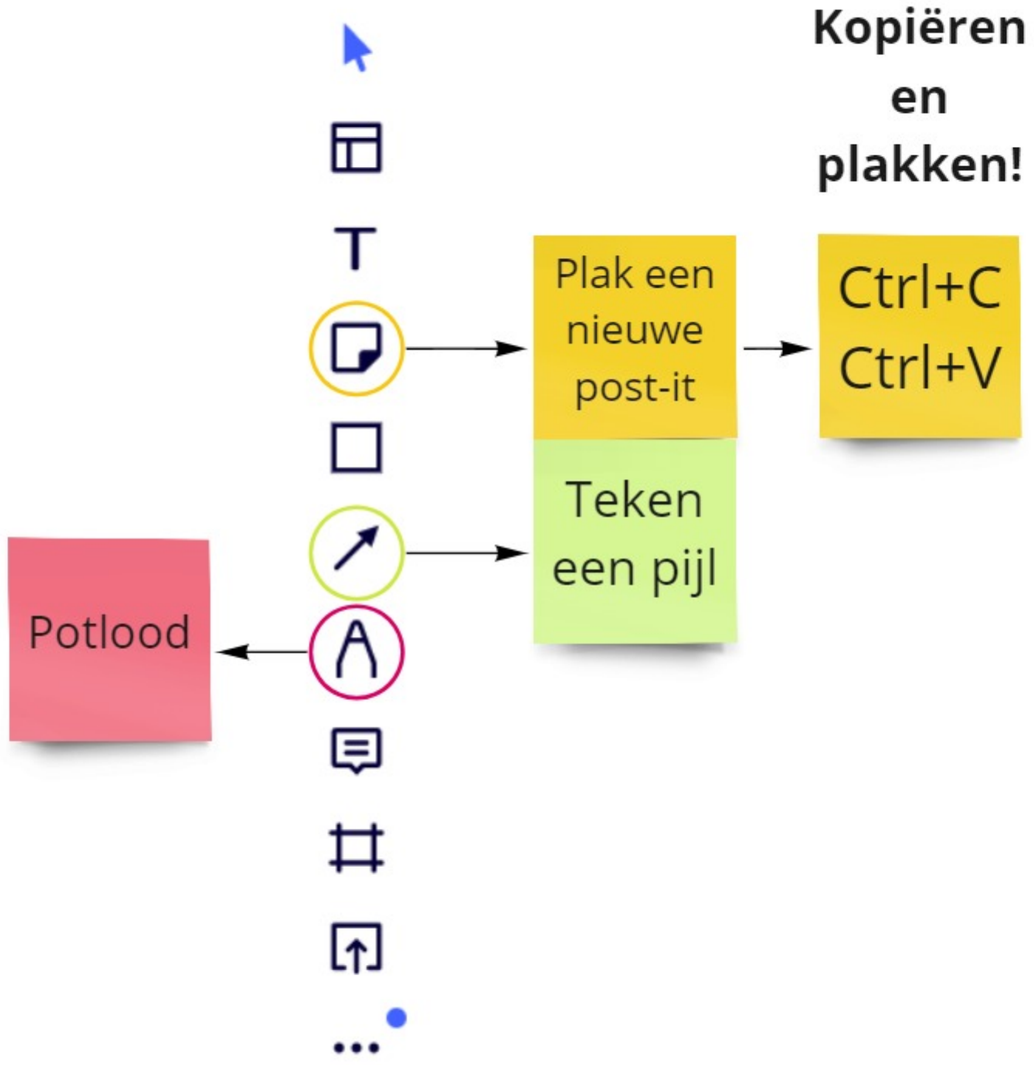
ik wil graag op de hoogte gehouden worden! :-)

benieuwd naar het eindresultaat

Heel veel succes met afstuderen

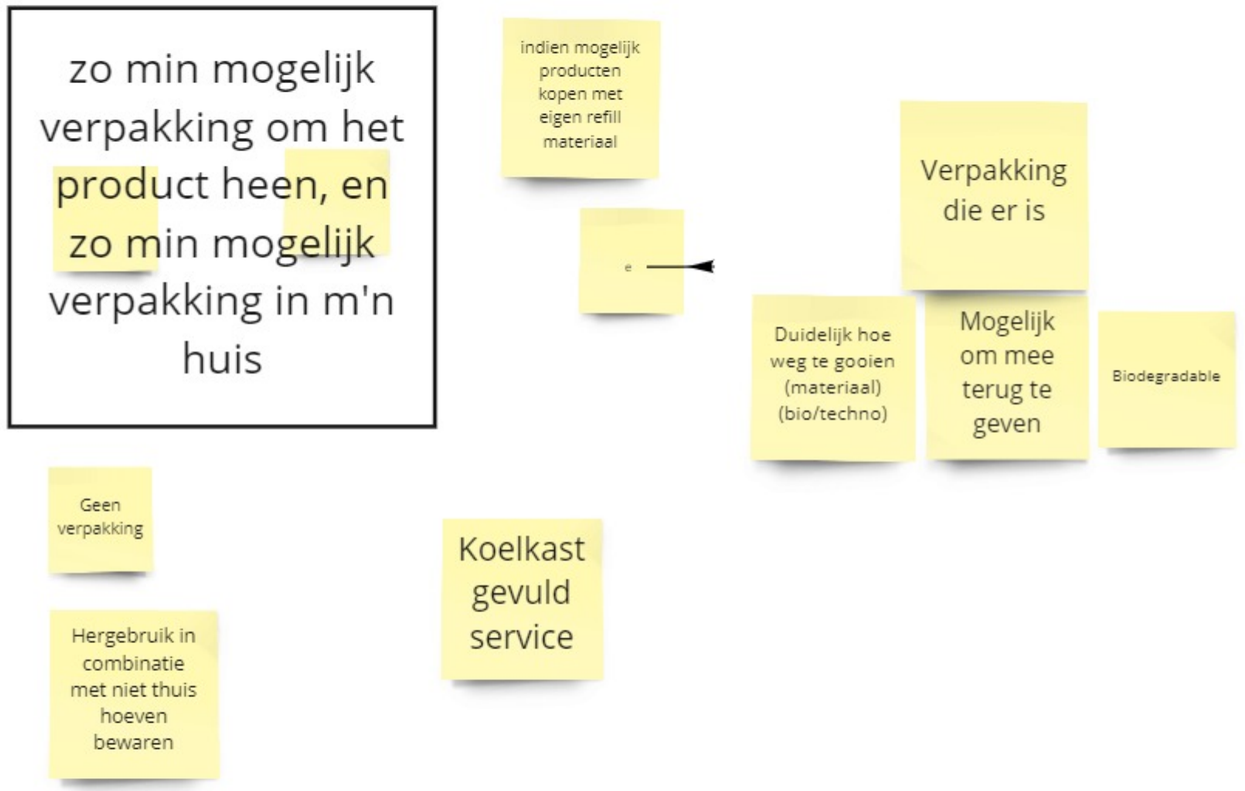
Hoe werkt miro ook alweer?

Gelukkig gebruiken we maar 3 functies



Hoe ziet jouw ideale ervaring eruit met circulaire verpakking?

10 - 15 Minuten



Appendix Q

Weighted criteria

Weighted Criteria

	Weight	Fiber box	Bounce Box	Bag-in-Bag
The solution shows potential to keep products cooled efficiently within the required timeframe.	5	4 Fibers are a proven insulator. Non-adaptable size implies inefficient cooling.	2 Multiple air chambers to minimize convective heat transfer. Non-adaptable size. Stiffness is crucial.	3 Thick air layer allows convective heat transfer. Cooled volume is always fitting to the product efficiently.
The solution shows potential to keep cost to keeping products flowing be as low as possible.	4	2 Relatively higher cost price Long lifetime Cost for reverse logistics is high because of size.	3 Relatively medium cost price. Medium lifetime. Costs for reverse logistics are higher because of its size.	5 Relatively low cost price. Medium lifetime. Costs for reverse logistics are estimated to be the lowest.
The solution shows potential to keep itself in the loop for as long as possible.	3	4 With usage of rigid materials this concept is expected to last the longest.	2 The air cushions lower the expected lifetime despite the rigid top and bottom plates.	2 Air cushions lower the lifetime. Creating more chambers becomes critical to improve and guarantee performance.
The solution shows potential to keep the environmental impact minimal compared to current solutions.	2	3 Potential use of recycled plastics in combination with plant based insulation combines for a low impact concept.	3 Potential use of recycled plastics in combination with air insulation combines for a low impact concept.	4 Using air as insulation is predicted to have the lowest impact of these three concepts.
The solution is innovative and fits with the use case (shipping food and logistic process).	1	3 This concept is innovative and has the potential to make use of dutch waste streams. It could become an asset for Goodcase but the high cost for reverse logistics could form a problem in the long run.	2 This concept is innovative, however it costs remain considerable while its lifetime does not cover up for this.	4 This concept is innovative and has the highest potential of becoming an asset for Goodcase because of its feasibility with reverse logistics.
Total score		**49**	**36**	**53**