FROM LINEAR TO CIRCULAR:

An innovation strategy for Miscanthus based sustainable packaging

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- *Sophie*

Excecutive Summary

This thesis presents a circular innovation strategy for Miscanthus based packaging. In the wold, more and more plastic packaging is being used. A large part of the used plastics is single-use plastic packaging that is only used for a couple of minutes and then discarded. The discarded plastic packaging stays in the environment for hundreds of years. A solution to this is shifting from a single-use plastic packaging that does not degrade and uses a fossil resource, towards a new type of paper packaging that degrades when ended up in the environment and is from a renewable source. Miscanthus based packaging can fulfil this need. Elgra is a company that cultivates Miscanthus and is looking for new paper packaging applications. To come to a design challenge, an extensive analysis is performed on the internal and external context of Miscanthus and paper packaging. From this analysis, three different market criteria are formulated:

- Closed systems have a controllable environment
- A constant demand reduces market fluctuations
- The paper industry is complex

From these market criteria, the market of Schiphol airport was chosen to introduce Miscanthus based packaging. It meets all three criteria and can be a local for local packaging. From the market criteria, a design challenge is formulated. This thesis answers the following design challenge:

Design a circular innovation strategy for Miscanthus based packaging at Schiphol, with a local for local approach, taking into consideration the complex system of papermaking.

A deep dive into the market of Schiphol showed that introducing Miscanthus packaging at KLM catering services (KCS) is the most beneficial for Elgra and KCS. The design challenge is answered by presenting four different design artefacts that illustrate four different strategic routes that can be taken. The artefacts are implemented using a local for local approach, this means that the packaging is cultivated, produced, distributed, used and collected locally. In addition, an LCA is performed to measure the environmental impact of the four different artefacts. It showed that the 3D moulded products which were mechanically pulped had the lowest impact. To validate if the market fits the four design artefacts, a value proposition canvas is filled in. The final artefact which is the most likely to be implemented is the beauty case. This artefact illustrates how Miscanthus packaging needs to be pulped using mechanical pulping and is 3D moulded into its shape. The roadmap that is presented shows that in the first horizon, a first Miscanthus packaging (for example the beauty case) is implemented at KCS. The goal is to set up a viable business with Miscanthus packaging at is core. The second horizon of the roadmap has the goal to professionalise the business by buying production machinery to produce Miscanthus packaging in house. The third and last horizon has as a focus on expanding the business to produce packaging from other renewable crops with its own production facility, still fitting the local for local approach.

Glossary

Airside	Beyond customs on the airport
Bio-based	Derived from biomass, so a biological origin.
Biodegradable	Materials that can be broken down by microorganisms
BMC	Business Model Canvas
Cellulose	natural fibres, main component for paper
Compostable	Similar to biodegradable, materials that are broken down by microorganisms and provide the earth with nutrients.
ICA	Intercontinental flights
KCS	KLM Catering Services
Lignin	Together with cellulose main building block of a plant
Miscanthus	Miscanthus x Gigantues, a genotype from the Miscanthus species
Non-invasive	Does not proliferate and is sterile
Primary packaging	Packaging that most closely protects the product (United Packaging, 2018)
Recycling	Taking apart products to separate materials and reusing them for new purposes (often products)
Renewable	Material collected from resources which are
naturally	replenished such as wood or grasses
SDGs	Sustainable Development Goals
Secondary packaging	Packaging that is used for branding or displaying the product (United Packaging, 2018)
Tertiary packaging	Packaging used for protection of the product during transport (United Packaging, 2018)

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Chapter 01 |

PROJECT INTRODUCTION

1.1 Introduction

The 'Sewage Surfer' (figure 1), is a photograph made by Justin Hofman in 2017, finalist of the Wildlife Photographer of the year award, commissioned by the Natural History Museum (Natural History Museum London, n.d.). A famous image that went viral, not only because of its beauty and composition but also because it shows a glimpse of the depressing amount of plastic waste in the oceans across the planet at this moment.

More and more plastic is being used and produced in this world; in the last 65 years, the annual production of plastic has increased to 381 million tonnes in 2015 (Our world in data, 2018). Plastic has many great advantages and is perfect for creating packaging: it is lightweight, flexible and waterproof. Besides, it is relatively cheap to manufacture. However, less than 1% of global plastic production is bio-based and/or biodegradable (van den Oever et al., 2017) and the main resources to produce plastic are fossil and, therefore, finite. When plastic ends up in nature it can have negative effects on its environment because it is not broken down into natural components and this results in pollution of the environment. Animals accidentally eat plastic because they mistake it for a food source, or like the image of Justin Hofman shows, can mistake it for a plant or other natural elements. This

Figure 1: Miscanthus growing in the Haarlemmermeer

poses a large threat to all-natural life on the planet. In other words, the problem with plastic is not the use of it but the discarding of it (Magnier & Schoormans, 2015). Around 9% of all used plastic is being recycled in the world (Parker, 2018). The other 91% of the used plastics end up in nature, in landfills or is being burned which results in large amounts of greenhouse gasses entering the atmosphere (Parker, 2018).

To reduce the amount of plastic that is being produced and to increase the amount of plastic that is being recycled, around the world, a lot of initiatives are emerging. These initiatives are operating from various angles, varying from finding natural resources to replace plastic such as paper-like materials to be used for packaging, to avoiding using single-use plastics or recycling and reusing existing materials. All these initiatives have one common goal, which is to move from a "take, make, use and dispose of" economy to a circular economy (Ellen Macarthur Foundation, 2013).

1.1.1 Why circular?

Many believe that the future economy is not about constant growth and using the world's recourses to achieve this growth but that (economic) growth should be decoupled from the use of resources by moving from a linear use of resources to a circular use of recourses (Ellen Macarthur Foundation, 2013) (Planing, 2015) (Ghisellini, Cialani, & Ulgiati, 2016). Within a circular economy, new products would keep their product integrity as long as possible before reaching end-of-life (Bakker, den Hollander, Peck, & Balkenende, 2019). Product integrity is defined by Bakker et al (2019) as "the extent to which a product remains identical to its original state, over time". Considering a circular innovation strategy, the loop between use and reuse should be short. This means, for example, a product that can be repaired should be repaired and not discarded.

Shifting from a linear to a circular economy provides companies with new opportunities. It is estimated that the transition would provide the global economy with one trillion USD (Planning, 2015). Besides, it will help companies to save costs in terms of reducing the material bill and disposal costs (Ellen Macarthur Foundation, 2013). For consumers, the circular economy can be beneficial in many ways, benefits are for example in terms of pricing, refurbished goods with similar product integrity can be sold at a lower price compared to new products because only some components of the product are replaced with new ones instead of producing a whole new product. Besides, the benefit of a circular economy is that it will eventually improve the quality of life (Ellen Macarthur Foundation, 2013).

In 2010 the Ellen MacArthur Foundation was founded by Ellen Macarthur (Ellen Macarthur Foundation, 2013). This foundation strives to create a new economy based on a circular model instead of a linear one. With the use of many experts from the field, the Ellen Macarthur foundation came up with a visual representation of a system that describes all necessary steps to create a fully circular economy with a strong focus on resources, see Figure 2.

For this thesis, the visual representation of a circular economy formulated by the Ellen Macarthur foundation has proven to be of great value. It shows the foundation of a circular economy. The right side of the model explains the technically complex products and services such as consumer electronics. While the left side of the model displays the biologically based products. An explanation of the model in more detail can be found in appendix A.

Figure 2: Ellen MacArthur foundation model

When looking at packaging and the environmental burden it has, as described in Section 1.1, there is an opportunity of creating sustainable packaging following the circular economy philosophy provided by Ellen MacArthur. Packaging can never be eliminated, since products we produce and distribute need for example protection during transport to prevent damage or to preserve freshness (European Bioplastics, n.d.). Besides, the problem of plastic packaging is not the use, but discarding it (Magnier & Schoormans, 2015), new types of packaging need to be created which will be sustainable alternatives for the fossil-based packaging. One way for packaging to become more sustainable is to introduce it within a circular system. By creating packaging from a biological source, it can follow the path on the left side of the system (Figure 2) where it is decomposed and has the potential to become a carbon-neutral packaging, leaving no negative impact on the environment.

1.1.2 Sustainable packaging

In the current literature, many different definitions can be found that define sustainable packaging. Since there are many different definitions, it is important to define sustainable packaging and keep this definition constant throughout the design process of this project. For example, Magnier, Schoormans, & Mugge (2016) define packaging sustainability as reducing the carbon footprint of a product by altering the packaging. Nordin & Selke (2010) define sustainable packaging as

"integrating the broad objectives of sustainable development to business considerations and implementing strategies that address social aspects as well as environmental concerns related to product/package systems, its entire life cycle throughout each stage of the supply chain.".

The Sustainable Packaging Coalition (2011) (SPC) is an international coalition that aims to unite the industry to develop sustainable packaging. They aim to work to the common vision of a closed-loop system for all packaging materials. The SPC formulated based on insights and research from the industry eight criteria for packaging sustainability:

- Is beneficial, safe & healthy for individuals and communities throughout its life cycle
- Meets market criteria for performance and cost
- Is sourced, manufactured, transported, and recycled using renewable energy
- Optimizes the use of renewable or recycled source materials
- Is manufactured using clean production technologies and best practices
- Is made from materials healthy throughout the life cycle
- Is physically designed to optimize materials and energy
- Is effectively recovered and utilized in biological and/or industrial closed-loop cycles

Since these criteria cover all aspects of the life cycle of packaging, these will be considered within this thesis as a definition for sustainable packaging. Throughout this thesis, the criteria formulated by the SPC will be used to measure whether the final design can be considered as sustainable packaging.

New sustainable material has emerged which will be the focus of this thesis, this new sustainable material has as a main resource Miscanthus (Figure 1). Miscanthus is a crop that can be used to create a paper-like material that can be manufactured as

sustainable packaging. Miscanthus has many advantages as a crop, it is renewable, has a high yield and does not need pesticides or extra nutrition (Beale, Bint, & Long, 1996) (Clifton-Brown et al., 2001) (Lewandowski, Clifton-Brown, Scurlock, & Huisman, 2000). This will be further elaborated on in Section 2.1. The Miscanthus crop has many benefits for its environment, such as sound-dampening and captures dust particles coming from exhaust fumes, therefore the assumption is made that there is a possibility for a local for local production of Miscanthus based packaging.

1.1.3 Local for local

The local for local principle describes that the products are locally produced, manufactured, distributed and preferably also used and recycled, without the necessity of transporting the products between different companies around the globe. The assumed benefits of local for local production are the reduction of transport and in the case of Miscanthus the possibility of producing carbon-neutral packaging. Miscanthus grows on nitrogen and CO2 from exhaust fumes resulting in a negative impact, in combination with the lower amount of emissions coming from transport resulting in a net-zero carbon emission packaging. This assumption will be that the local for local principle will be beneficial for Miscanthus based packaging which will be testing in this thesis by creating an LCA and examining costs of a single Miscanthus based packaging.

1.1.4 Stakeholders

This thesis has two main stakeholders. The commissioner of this master thesis is Kenniscentrum Papier en Karton (KCPK). KCPK is a non-profit organisation that is mainly focussed on generating knowledge and disseminating that to companies operating in the paper industry.

For KCPK it is important to know the possibilities of Miscanthus fibres. It is relevant because this thesis will look at the product life cycle of Miscanthus based paper products and the implementation of it in the market. This thesis can contribute to KCPK by researching the possibilities of packaging made from Miscanthus and the possibilities for it being implemented using a circular model.

The second stakeholder is the company Elgra that cultivates Miscanthus and aims to be producing Miscanthus based packaging. Elgra name is a conjunction of Elephant and Grass, the English translation for the Dutch word Olifantsgras (Miscanthus). This thesis will contribute to this company by investigating the possibilities of Miscanthus-based paper packaging and providing them with an innovation strategy.

A more elaborate company analysis will be given further in the report where both stakeholders will be investigated in more detail (Section 3.1).

1.2 Project Purpose

Currently, Miscanthus is being cultivated and harvested around the Schiphol airport area. Elgra harvests and sells the cultivated Miscanthus to various parties. However, these parties are only creating low-grade applications of Miscanthus. These low-grade applications are often short-term; currently, Miscanthus is e.g. used to create briquettes for heating homes, or it is chopped and used as floor bedding at festivals to absorb moist from the ground and to create a dry surface for the festival visitors to walk on. These applications are circular but not optimizing the use of the crop. After one time use, it is discarded and cannot be retrieved, making cascading difficult.

Miscanthus has the potential to become a circular packaging material since the fibres the plant contains are long (Ververis, Georghiou, Christodoulakis, Santas, & Santas, 2004), meaning it can be recycled more often and be used to create a high-grade packaging paper material (Ververis et al, 2004). Therefore, it is a waste of a good resource to use it as floor bedding or burn for heat production.

Regular (wood) paper is mainly used for graphical paper, for example, to write and print on. Using paper in the packaging industry is becoming more and more common (McKinsey & Company, 2019), however, still a lot of plastic is being used to create packaging. The advantage of using paper instead of plastic as a packaging material is its biological heritage (McKinsey & Company, 2019). In the Netherlands, around 85% of all the paper is already being recycled, besides all paper produced in the Netherlands, also consists out of 85% recycled fibres (Papierenkarton.nl, 2019). Although paper packaging is a more sustainable option compared to plastic packaging, the main component of paper is still cellulose from trees which take around 30 years to grow and to be ready for harvest (Paper Chase, 2011). Miscanthus needs no pesticides and fertilizers to grow (Beale, Bint, & Long, 1996) (Clifton-Brown et al., 2001) (Lewandowski, Clifton-Brown, Scurlock, & Huisman, 2000) and can be harvested using regular machinery making it relatively easy to cultivate, this is further elaborated on in Section 2.1.

Papermaking is currently the fourth most energy-intensive business in Europe (EU Science hub, 2018), by creating packaging from Miscanthus using low environmental impact paper making techniques, it could contribute in making the paper industry cleaner. However, there is not much known about how to introduce a paper material from Miscanthus in a circular system and what a potential market could be to introduce the packaging material. To explore this in this thesis, the following research questions are formulated:

RQ1: How can sustainable packaging made from Miscanthus be developed using a circular innovation strategy?

Since the starting point of this thesis is a new kind of material, a possible market position also needs to be investigated. Therefore, a second research question is formulated:

RQ2: How to position a new type of sustainable packaging made from Miscanthus on an existing market?

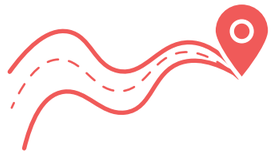
Some limitations need to be considered. First, there is a limited budget available. Currently, all financial resources are private investments or subsidies. Second, there are some developments in the production methods for paper-based packaging from Miscanthus, however, these are not ready for full-scale production yet. Lastly, Miscanthus is an opportunity for sustainable packaging, however for it to meet the packaging criteria and to have the right barrier qualities for certain applications, chemical components need to be added and this might have a negative effect on the circularity, this assumption will be further investigated in this thesis.

1.3 Methods & Approach

CONTEXT EXPLORING

DEEP DIVE & SYNTHESIS

CIRCULAR INNOVATION STRATEGY BUILDING



FUTURE AND CONCLUSION

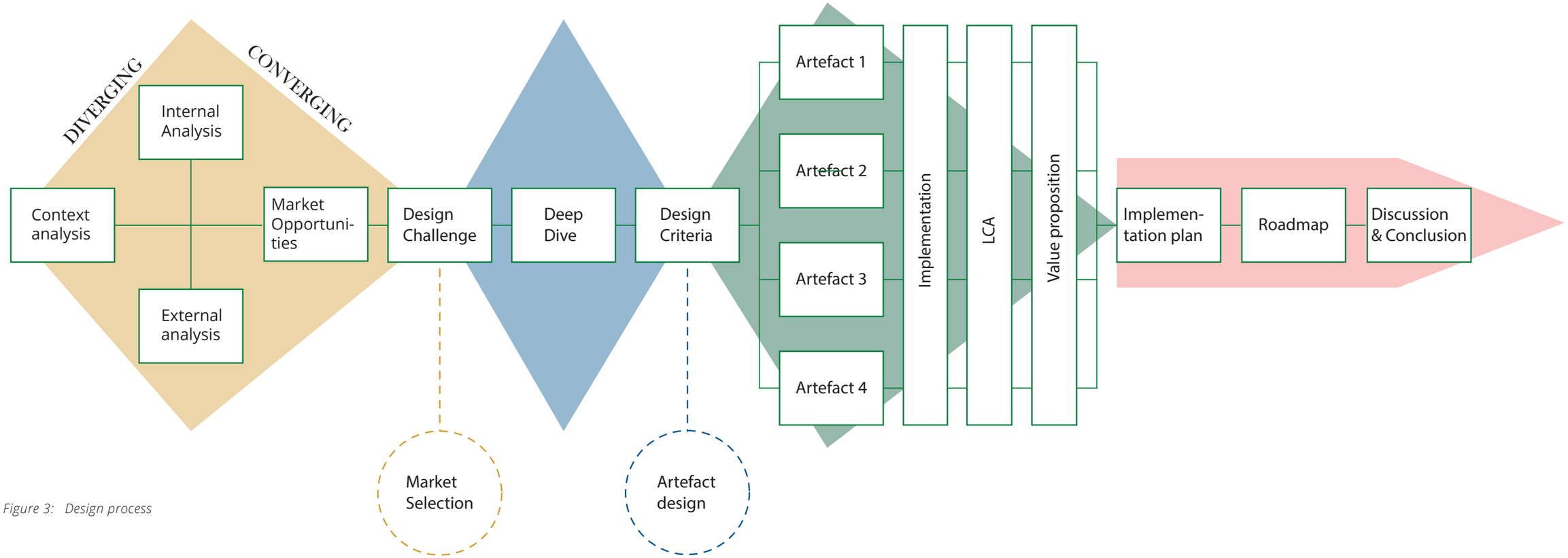


Figure 3: Design process

This thesis will aim to answer the research questions by designing a circular innovation strategy for Miscanthus and exploring a possible market positioning. The approach will be following a triple diamond strategy. The original model, the double diamond created by Design Council (Design Council, 2018), describes four phases: Discover, Define, Develop and Deliver, in the first diamond the problem is analysed, in the second diamond a solution to the problem is proposed. However, since this project does not already start with a potential market in mind, an extra diamond is added in between the problem formulation diamond and the proposed solution diamond. In Figure 3, a visualisation of the triple diamond approach for this thesis can be seen. The first diamond focusses on getting a grasp on the context, the second diamond that is additional to the double diamond approach focusses on doing a deep dive into a specific market and the last part of the thesis is a concluding phase where the focus lies on providing an implementation plan, a concluding roadmap and a discussion/conclusion of the thesis.

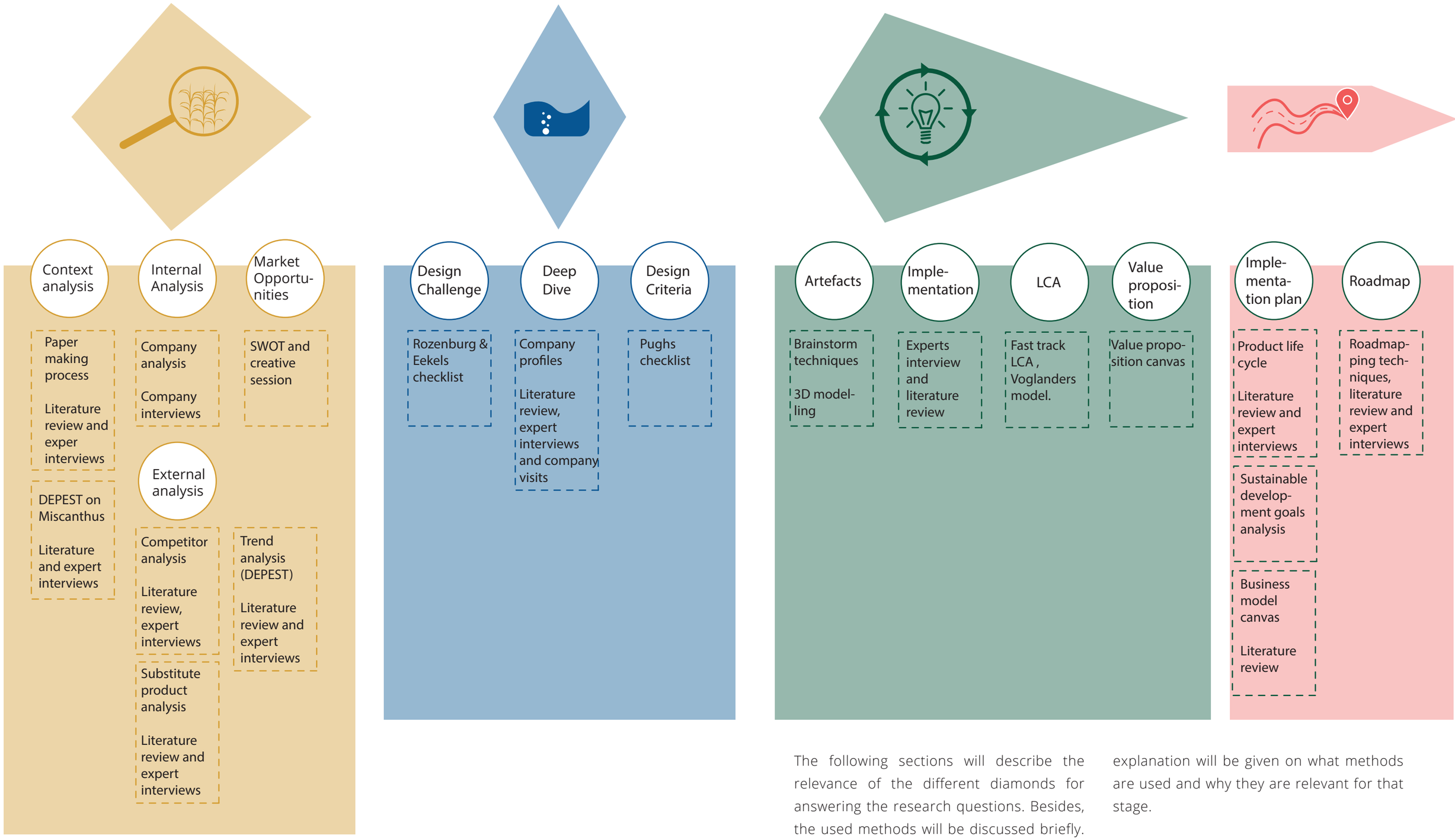


Figure 4: Methods

The following sections will describe the relevance of the different diamonds for answering the research questions. Besides, the used methods will be discussed briefly. In Figure 4, an overview of the used methods is shown. In each chapter, a more elaborate explanation will be given on what methods are used and why they are relevant for that stage.

1.3.1 First diamond: Context exploring

The first diamond focusses on analysing the context around Miscanthus and (paper) packaging in general. It will contain an internal analysis focussing on the company, which looks at the stakeholders of the project, and an external analysis that will look at the industry forces and a general trends analysis. The insights gained from these different analyses will help in answering both of the research questions because it will show the design direction which will be used for the next stages. The first diamond will finish with market criteria that will provide a guideline for choosing a specific market for Miscanthus based packaging. Based on the insights, Schiphol airport is chosen as an interesting market segment to further investigate in the second diamond. To structure the second diamond, and as an elaboration on the initially stated research questions, a design challenge is formulated. This will give guidance for the next diamond.

1.3.2 Second diamond: Deep dive & Synthesis

The second diamond starts from the previously defined design challenge. A market segment emerged from the creative session which meets the market criteria formulated based on the SWOT analysis, which is Schiphol Airport. This phase will start with a deep dive into Schiphol airport as a potential market for Miscanthus based packaging. The deep dive will examine this opportunity further and test the assumption that it is suitable for Miscanthus packaging. From the deep dive it becomes clear that for Miscanthus based packaging, KLM would be the most suitable partner as launching customer at Schiphol airport. The second diamond will end with a list of product criteria for Miscanthus based packaging which will be used to design possible design artefacts to explore the different possible design routes.

1.3.3 Third diamond: Strategy building

The third diamond focusses on the strategy building of Miscanthus based packaging and to examine possible strategic decisions that can be taken with the use of design artefacts to introduce Miscanthus based packaging within KLM. After defining the four artefacts, they will be further examined based on feasibility, viability and desirability. Within the faculty of Industrial Design Engineering, the design thinking methodology is widely implemented (Figure 5). The feasibility will be tested by examining the batch size, the different production method for each of the artefacts and an LCA will be done to determine which production method will have the lowest environmental impact. Viability will be tested with a costs analysis to determine whether the production price of the design artefacts is competitive with similar (sustainable) packaging alternatives. Desirability will be tested by using the value proposition canvas to determine the value of the design artefacts for KLM.

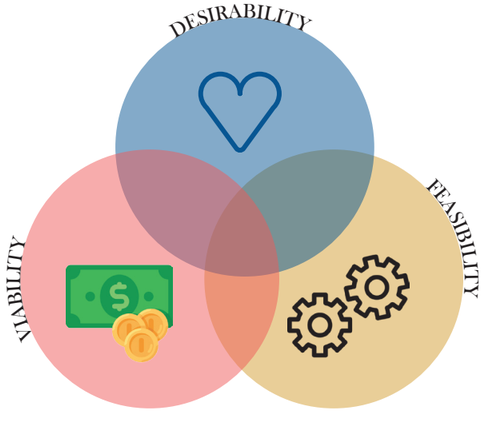
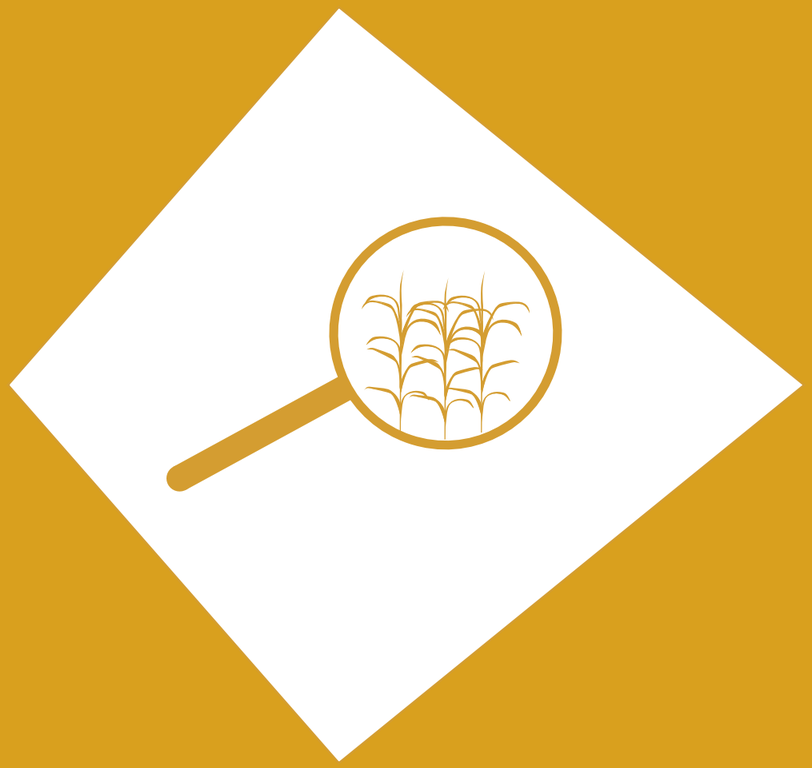


Figure 5: Design thinking model

The last phase of the thesis will conclude with a short-term implementation plan and a long-term roadmap to provide Elgra with guidelines on how to continue with the implementation of Miscanthus based packaging.

Since a design process is never linear, constant revision of the previous steps is necessary to ensure accurate decisions based on the latest gained insights. This is done by validating the thesis with experts within KCPK and reading relevant literature about paper packaging, Miscanthus and circular economy. This thesis will provide information based on literature and expert knowledge to determine a strategy for Miscanthus based packaging but will also explore the concept of local for local and how this can be extrapolated to other areas within the Netherlands. It will conclude with a strategic advice on what decisions on the development of Miscanthus based packaging needs to consider and whether these decisions also apply for other fibre materials.

CONTEXT EXPLORING



The following phase is the context exploring phase. This phase consists out of literature research on the current developments of Miscanthus, paper packaging, an internal analysis and an external analysis. It will provide this thesis with a literature background. The information in this chapter will be used for answering the research question, formulating market opportunities and a design challenge.

Chapter 02 |
CONTEXT ANALYSIS

2.1 Miscanthus analysis

To get a better understanding of the Miscanthus crop and the available paper material, a context analysis has been performed. This analysis is done by doing literature research and talking to experts in the field of papermaking and Miscanthus cultivation. In this analysis, seven different aspects will be looked at. These seven aspects are geography, sociocultural, economic, regulatory, technological, natural environment and, biology. This analysis will show insights about the plant, the material and the broader context of introducing sustainable packaging to the market. This will be the starting point for this thesis. Besides, this analysis will examine whether one of these aspects will affect developing packaging made from Miscanthus. The insights gained from this analysis will be used as input for a SWOT analysis about Miscanthus to find market criteria and opportunities for determining a specific market for Miscanthus based packaging. This analysis will only look at already existing information about Miscanthus and its context, no tests will be done, at Section 4.2, also a trend analysis will be performed that will look at future trends in the industry.

There are multiple variations of the Miscanthus genome, this thesis will only consider the Miscanthus x Giganteus. This is the crop that is being cultivated by Elgra and where KCPK has shown an interest in. Other Miscanthus species are currently limited available in the Netherlands and do not have the same potential to create paper. Whenever Miscanthus is being mentioned in this thesis, Miscanthus x Giganteus will be the referred species, unless mentioned otherwise.

2.1.1 Biological aspects

The biological aspects of Miscanthus describe the natural qualities of Miscanthus as a crop and the effects of it on the packaging material. In addition, this section will describe the biological history of Miscanthus and what already has been tested in the past. This is relevant for answering the research questions because it will show what is necessary to consider when designing Miscanthus based packaging such as fibre length and cultivation.

The Miscanthus as a crop grows well in colder climates, making it suitable for cultivation in the Netherlands. Further reading about the genome of Miscanthus can be found in Appendix B.

The fibres of Miscanthus are used to create paper packaging. In the papermaking process, the fibres link together to form the material as we know it, this is further discussed in Section 2.2. When looking at Table 1, Miscanthus has a similar cellulose content compared to the other crops, which is also similar to regular (wood based) wastepaper, making it suitable for paper production. Ververis et al (2004) concluded in his study that the fibre length of Miscanthus is between 0.94 and 0.99 mm, depending on the point of measure on the plant, when measured at the base of the plant, the fibre length differs slightly from measuring the fibre length at the top of the plant. The fibres are relatively thin and have a good slenderness ratio (>60), meaning that when pulped for paper production, is has good tear indices and bursting strengths resulting in high quality paper (Ververis et al., 2004).

Table 1 shows the natural build-up of Miscanthus compared to other crops, expressed in percentages of dry matter (all water extracted). As can be seen, the cellulose content is between the 37% and the 40%. From the cellulose, paper material can be created. By looking at the production process of creating paper, the cellulose content determines the efficiency of the paper production (Ververis, Georghiou, Christodoulakis, Santas, & Santas, 2004). The last column shows the lignin content of the different crops. Lignin is being used to produce heat and electricity by combustion. When all the crops are compared, Miscanthus has a high percentage of lignin, making it useful for heating purposes (Khanna, Dhungana, & Clifton-Brown, 2008) (Brosse, Dufour, Meng, Sun, & Ragauskas, 2012). The percentages of the table do not add up to 100%, this is because the last part of the crops consist of a variety of components such as hemicellulose, ash, silica or proteins.

Table 1: Content raw material comparison, souce: Adriaanse, personnal communication (2019)

Material	Cellulose (% TS)	Lignin (% TS)
Grass	25-40	18-25
Straw	38-42	19
Cornstraw	37-40	6
Miscanthus	37-40	24
Hardwood	40-55	18-25
Wastepaper	38-44	5-15
Bagasse	35-43	11-22

There are not many insects or pests that affect Miscanthus. There have been no records to show a loss in yield due to pests and insects (Anderson et al, 2011). In addition, Hein van Elderen (9-5-2019), a Miscanthus farmer in the Haarlemmermeer who was interviewed for this thesis, also confirmed that in the 10 years they have been cultivating the crop, no deceases or insects have harmed the crop. When looking at the material made from Miscanthus, having to use no pesticides means the material can be made 100% biological.

Miscanthus needs to be propagated using rhizomes. Figure 6 shows an image of a Miscanthus rhizome. The reason for this way of propagating Miscanthus is because it is a sterile crop that does not produce seeds (Lewandowski et al, 2000; Anderson et al, 2011). These rhizomes stay in the soil for as long as Miscanthus is being cultivated on that plot of land. The rhizome serves as an overwintering storage for the plant's nutrients. Which are being used again each year (Anderson et al, 2011). Miscanthus grows between the 3 to 4 meters high (Anderson et al, 2011; Lewandowski et al, 2000). The roots grow around 1,8m deep (Anderson et al, 2011), for comparison, the roots of normal corn cultivated in the Netherlands grows over 85cm in depth, with records of 1,8m in depth (Van Lieshout, 1956). Because of the high crop and the deep running roots, the crop is difficult to remove from the ground. From this can be concluded that when farmers decide to cultivate Miscanthus, they must be aware that Miscanthus will need more attention when it is removed.

There are developments to produce seeds from the Miscanthus crop to replace the current way of planting rhizomes (Boer en Business, 2015). When there are seeds available from Miscanthus, there is a

possibility that planting will become less labour intensive, meaning it can reduce costs and making scaling up easier. There are however also challenges such as Miscanthus not being sterile anymore which can result in it becoming invasive in the Dutch natural environment.

Conclusion

The biological aspects of Miscanthus such as the crop not needing fertilizer, aid having a better chance at becoming an environmentally neutral packaging material. The crop does not need any fertilizer or pesticides help in creating a 100% biological material. This adds to the positive brand positioning that can be used when introducing Miscanthus to the market and help in creating a sustainable packaging.

The percentage of cellulose content shows that it is equal to other crops used for paper production, this means that Miscanthus is suitable for paper production. In addition, miscanthus fibres have a good fibre length and high slenderness, this is beneficial for higher quality paper.

Figure 6: Miscanthus Rhizome

2.1.2 Natural environment

This paragraph will describe the ideal growth circumstances, the growth cycle of Miscanthus and the natural environment of Miscanthus as a crop. Based on this, the effect of the natural environment on packaging development of Miscanthus will be examined. From this analysis it will become clear whether there are opportunities for Miscanthus based packaging, using a local for local principle.

Between 1983 and 1993 several large tests have been done with Miscanthus in Denmark, Germany, Ireland and the UK, and later also in southern Europe including Greece, Italy and Spain to determine the characteristics and potential in Europe (Lewandowski et al, 2000; Anderson et al, 2011). In Europe around the time of the tests, was 170 ha in total, which is only slightly more than is currently available in the Netherlands. Lewandowski et al (2000), describes the benefits of Miscanthus for lignine extraction for heating purposes and cellulose extraction for purposes but sees disadvantages of planting Miscanthus using rhizomes because of the high costs compared to seed plantation. The results from the tests showed that Miscanthus has agronomic advantages, which are the high yields (20-ton dry material ha-1 year -1) (Lewandowski et al, 2000; Anderson et al, 2011). Once it is planted, it stays in the ground for a long time. Anderson et al wrote in 2011 that the oldest European Miscanthus plantation has been standing in Denmark for over 25 years. When a new plot of Miscanthus is being selected for cultivation, the landowner must be aware that the crop will stay on this land for 25 years and must be harvested each year (Anderson et al, 2011). Figure 7 shows a visual of the natural growth cycle of Miscanthus.

In the first year, Miscanthus needs to be protected against pesticides and needs to be fertilised (Lewandowski et al, 2000), after the second and third year, the plant matured enough that it does not need any fertilizer or protection against pesticides (Anderson et al, 2011). It reaches maximum yield in the third year it is planted which will be stable for the time it is planted (Anderson et al, 2011).

Miscanthus sheds its leaves every year as can be seen from Figure 7 The shed leaves from, increase the soil fertility (Lewandowski et al, 2000) (Elderen, personal communication, 9-5-2019), the roots of the plant make sure the ground is not depleted from nitrogen (natural nutrition for plants). The only concern is that because the roots reach so deep (1.8m according to Anderson et al (2011)) after the first couple of years that the ground water lowers and is hard to restore to its original levels (Lewandowski et al, 2000).

The canopy of Miscanthus has the advantage to offer shelter to smaller sized vertebrates such as rodents or small birds. Research has shown that the biodiversity increases within Miscanthus fields (Semere & Slater (2007)). For larger birds, such as geese, Miscanthus fields are not attractive. The airport of Schiphol planted Miscanthus as a solution for the hindrance of geese in the area. Geese like to graze on grass fields but with Miscanthus this is not ideal. For an airport, geese can be a massive problem, when they fly around aircrafts, there is a possibility they get sucked into the engine, severely damaging the aircraft (Luchtvaartnieuws, 2014). Resulting in delays and dangerous situations (Luchtvaartnieuws, 2014). The height of Miscanthus hinders geese to land in the field (Elderen, van, personal communication, 2019). When Miscanthus is harvested, the hard stalks still stay around 30cm high, making it unpleasant for geese feet to stand on (Elderen, van, personal communication, 2019). It becomes a natural barrier and animal friendly way for hindering geese (Wageningen University & Research, n.d.). Alternative methods of hindering geese are shooting them or gassing (Luchtvaartnieuws, 2014).

Concerning the growth of Miscanthus, it grows well in the Netherlands because of the relatively soft weather and many rain days (Clifton-Brown et al., 2001). For Miscanthus to grow, the ground should not be colder than -3 degrees (Clifton-Brown et al., 2001). Since 2006 in the Netherlands, the soil temperature did not go below 0 (measured up to 1m below the surface) (“NL soil temperatures,” n.d.), Miscanthus will be growing well in the Netherlands.

Conclusion

For the development of packaging of Miscanthus, it is an advantage that it grows well in the Netherlands, making it an attractive crop for local to local production because it has many benefits for its environment such as increase in biodiversity, hindrance of geese and increase in soil fertility. Since the yield of Miscanthus is only optimal after three years, this has a significant effect on the scalability of the packaging development. All qualities of the natural environment of Miscanthus combined can help in creating a positive story to help with the brand positioning of the sustainable packaging that can be created from Miscanthus. In addition, the local for local aspect is an opportunity for Miscanthus based packaging since it has benefits for its surroundings, as described above.

MISCANTHUS CULTIVATION PROCESS

Rhizomes are planted by hand

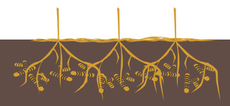
It takes three years for Miscanthus reaches maximum yield

Miscanthus grows from April to September

After the first frost in September, the plants nutrients are stored in the rhizomes.

From September to March, the stalks dry out.

In April, the Miscanthus is harvested and chopped to the right size. New sprouts will start to grow from the rhizomes that are already in the ground.



2.1.3 Geography

This paragraph will look at the geography of Miscanthus. It will also discuss the advantages and disadvantages of Miscanthus being cultivated in these locations and will investigate if there is an effect on the potential of packaging made from Miscanthus. The scope of this project is the Netherlands, some additional reading the migration of Miscanthus can be found in Appendix B.

When looking at the current locations of Miscanthus in the Netherlands, the largest area it is being cultivated, is around the airport of Schiphol (municipality of Haarlemmermeer) (de Jong, personal communication, 2019; Adriaanse, personal communication, 2019; Elderen, van, personal communication, 2019). There are also some fields in Zeeland and around Arnhem, but these are respectively around 20 and 50 hectares, in the Haarlemmermeer around 70 hectares is planted (de Jong, personal communication, 2019; Adriaanse, personal communication, 2019, Elderen, van, personal communication, 2019). In Figure 8, a map (Wikipedia, 2012) can be seen that indicates the locations of the Miscanthus crop in the Haarlemmermeer.

Miscanthus was originally planted in the Haarlemmermeer area to help with noise reduction of ascending and descending aircrafts (de Jong, personal communication, 2019). Furthermore, the crop is also used to hinder geese around the airport (Elderen, van, personal communication, 2019; Wageningen University & Research, n.d.), as already described in Section 2.1.2.

Conclusion

The cultivation of Miscanthus around Schiphol can be an opportunity when looking at the local for local aspect. An assumption is that it can be cultivated around the airport, manufactured to packaging and used at the airport. In addition, with the benefits for the environment as described in Section 2.1.2, this can help in telling a positive story about the crop to consumers.

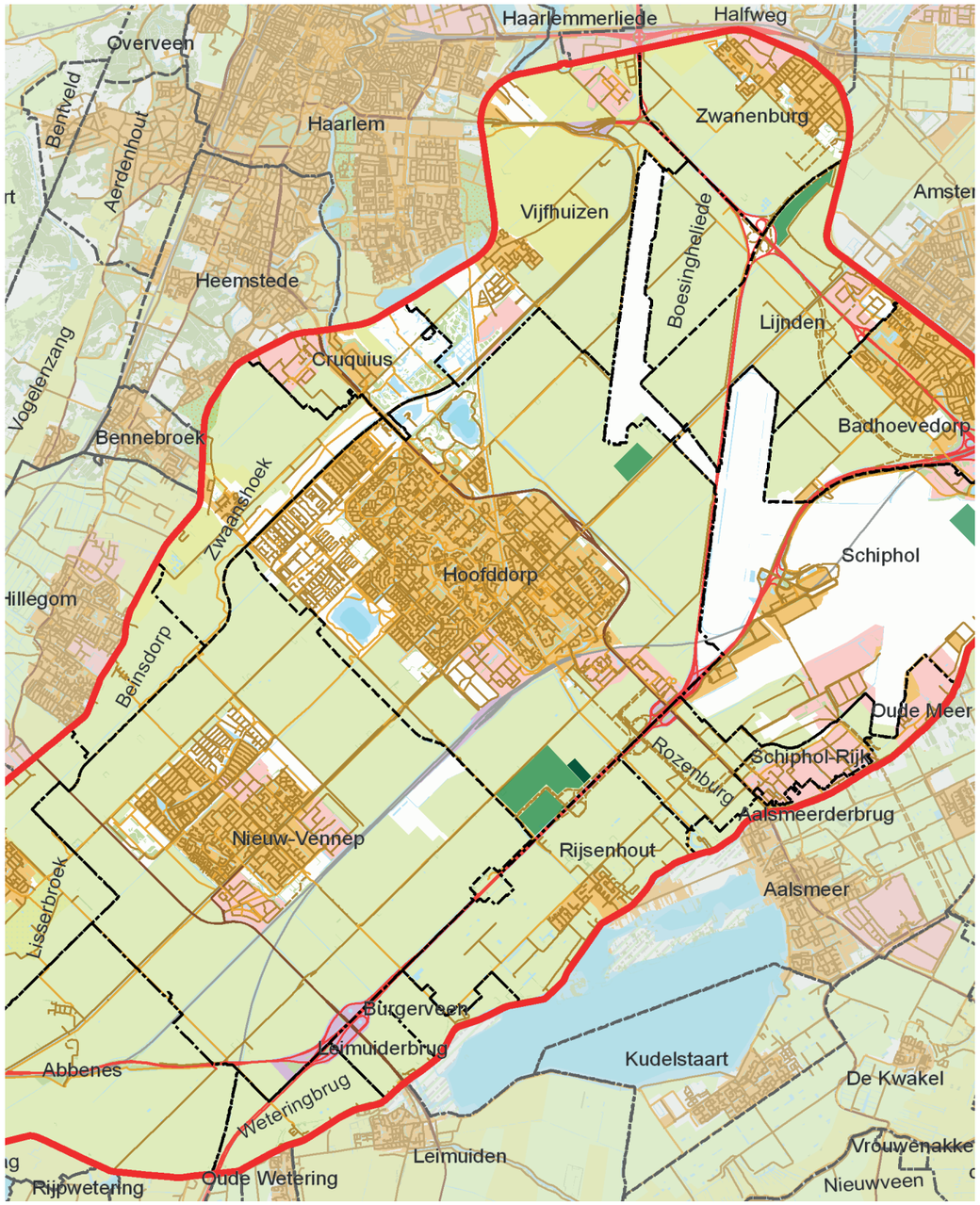


Figure 8: Miscanthus cultivation locations in the municipality Haarlemmermeer (Wikipedia, 2012)

Legend

- Regular Miscanthus cultivation sites
- Testing Miscanthus cultivation sites by SADC

2.1.4 Technological

For the technological aspects, a literature review has been done, together with an expert interview to identify the key takeaways of the technical specifications of Miscanthus paper, the full research can be found in Appendix C. The key takeaways are selected based on relevance for answering the research questions. It has been chosen to do a literature review on the technological aspects of Miscanthus because the goal of this thesis is to formulate a strategy and a global understanding of the material properties is necessary to identify the possible product opportunities of Miscanthus based packaging. This section only considers key takeaways of Miscanthus paper because the technical specification of the plant itself is already discussed in Section 2.1.1.

Current literature describes various results on Miscanthus based paper (Ververis et al., 2004; Cappelletto et al., 2000; Oggiano, Angelini, & Cappelletto, 1997; Marín, Sánchez, Arauzo, Fuertes, & Gonzalo, 2009). There are two different ways to develop Miscanthus based packaging, one is 3D moulding of paper pulp to create a stiff material that holds its shape, the other is sheet pressing, resulting in a paper sheet comparable to regular paper (de Jong, G, personal communication, 2019). Both packaging types have different specifications. Below, both types will be discussed.

The moulding of Miscanthus pulp has been done by Millvision this year (Millvision, 2019), commissioned by Elgra. For this thesis is chosen to only look at this research performed by Millvision, since the Miscanthus used for this study is the same Miscanthus as will be used for the final packaging strategy and the results are therefore best comparable to the outcome of this thesis. In addition, the production process is also the same as will be discussed in Section 2.2 to examine the possibilities of Miscanthus based packaging.

From the research of Millvision, it became clear that moulded Miscanthus packaging is a brittle material compared to moulded recycled paper (F. Voets, personal communication, 2019). This can be solved by mixing 50% Miscanthus pulp with 50% recycled paper, Figure 9 shows a sample from the study. By mixing Miscanthus pulp with recycled paper, the material becomes less brittle (F. Voets, personal communication). As can be seen in Figure 10, the blended paper pulp results in a grey material, estimated is that when the packaging is 100% Miscanthus, an unbleached product becomes more yellow (De Jong, G, personal communication, 2019).

The second way of creating Miscanthus based paper is by creating paper sheets. To examine the key takeaways, different international literature on Miscanthus paper has been evaluated (Ververis et al., 2004; Cappelletto et al., 2000; Oggiano, Angelini, & Cappelletto, 1997; Marín, Sánchez, Arauzo, Fuertes, & Gonzalo, 2009). From the literature, it became clear that Miscanthus is suitable for creating paper. Oggiano et al., (1997) did research on Miscanthus Sinensis, a parent genome of Miscanthus Giganteus (Appendix XX) and discussed that Miscanthus is suitable to create paper and that it demonstrates good physical-mechanical properties for printing paper purposes, when chemically pulped (extracting the cellulose from the lignin, the main building block of paper from the plant) and if bleached. Cappelletto et al., (2000) did similar research on Miscanthus based paper but looked more at mechanically pulping (grinding the plant with water to create a paper pulp still containing the lignin) Miscanthus, the results of this study also proved that Miscanthus is suitable for paper production. Oggiano et al., (1997), Cappelletto et al., (2000) and Marín et al., (2009) discuss that adding Miscanthus pulp to recycled paper pulp increases the mechanical strength of the paper and improving the technical specifications important for creating paper

Figure 9: Miscanthus trial product inside

Figure 10: Miscanthus trial product outside

2.1.5 Economic

This paragraph will look at what is already there in terms of pricing and cost structures for the growth and harvest of Miscanthus. When cultivating Miscanthus, several costs come into play. Table 2 shows an overview of the costs of cultivating Miscanthus.

The costs can fluctuate because it is depending on energy prices (Elderen, van, personal communication, 2019). The machines used to plant and harvest Miscanthus, use high amounts of fuel and are determining for the costs of these stages of Miscanthus cultivation.

Since Miscanthus needs to be planted using rhizomes and maximum yield is only reached in the fourth year, the costs of the first few years are higher (Elderen, van, personal communication, 9-5-2019). Furthermore, from the second year onward, Miscanthus grows so closely together, there is also no need to removing weeds anymore (Elderen, van, personal communication, 9-5-2019).

Currently, there is only a small margin on the crop Miscanthus. This is mainly because of the current small demand. When there is a higher demand, it might be taken into consideration to increase the margin. Miscanthus in the Haarlemmermeer is only sold as a raw product, the only processing they currently do is chopping it to the desired size and seal it in plastic for transport. The transport is done by the farmers themselves; these costs are not in the table because they are unknown, as transportation is still at small scale done by using private vehicles.

Conclusion

For packaging, the cultivation costs need to be considered when Miscanthus is being used to develop paper-based packaging. All costs presented in table XX are not likely to change, however, they are dependent on energy prices. The selling price of Miscanthus can change because it depends on the demand. This should be considered when creating a packaging material from Miscanthus. When the selling price of Miscanthus increases (now €0,20 per kg), this will have a direct effect on the selling price of the Miscanthus paper material. The price of Miscanthus is difficult to compare to other crops or paper making resources such as wood because of the large-scale differences. The selling price of wood is known but wood has a different composition compared to Miscanthus (Table 2), therefore a different percentage of cellulose can be extracted. Comparing wood to Miscanthus is therefore not possible. The price described in this section will be used for a cost calculation of a Miscanthus packaging.

Table 2: Costs of cultivating Miscanthus

What	How much	Additional information
Planting	3100 to 3200 euro p. ha	Selling price, so this price has some margin included.
Ground	1250 euro p. ha in Haarlemmermeer	Lease or ownership by farmers
Harvest	500 euro p. ha	Also includes processing costs (cutting to the desired size)
Miscanthus	20 cent per kg selling price	For raw material, same for all current applications
Extra costs such as ditch maintenance and storage costs	Low costs for ditch maintenance, unknown storage costs	

2.1.6 Regulatory

This paragraph will look at regulatory aspects that are currently in place concerning sustainability and other relevant regulations that might have an impact on bringing Miscanthus based packaging to the market. For this thesis, this is relevant because, in the final roadmap, the upcoming regulations and necessary certifications require time to adjust to. This time needs to be considered when developing a strategy. Besides, regulations that are already in place can be considered and provide insights for packaging criteria.

Plant regulations

Invasive species

Miscanthus as a crop does not originate from the Netherlands (Lewandowski, Clifton-Brown, Scurlock, Huisman, (2000); Anderson et al (2011)) and is therefore defined as an exotic species. The Dutch government has adopted rules and regulations concerning containing invasive plant species (Nederlandse Voedsel- en Warenautoriteit, 2019). A species is only considered to be invasive when it does harm to its environment and forms a threat to other native species (plants or animals) (Rijksdienst voor Ondernemend Nederland, n.d.). The Dutch government has created a list that shows all species that are exotic and invasive to the environment in the Netherlands (Nederlandse Voedsel- en Warenautoriteit, 2019). Miscanthus is not on that list and is therefore not considered to be invasive. This means it can be cultivated and sold without restrictions concerning invasiveness.

Packaging regulations

Plastic ban by 2021

In March this year, the European Parliament has adopted a new law that by 2021 single-use plastics will be banned in the EU (European Parliament, 2019). The single-use plastic items that will be banned are single-use plastic cutlery, plastic plates, plastic straws, cotton bud sticks, plastic balloon sticks and oxo-degradable plastics, food containers and polystyrene cups (European Parliament, 2019). These items are not essentially packaging items but are according to the European Parliament, the most polluting items. This law is assumed to be extended to also single-use plastic items, an example is the free plastic bag that banned in the Netherlands some years ago. The plastic ban should be considered in the roadmap, as an indication of when certain products will be banned and when Miscanthus based packaging can fill this gap.

Biodegradable packaging

For packaging, there is the possibility to make the packaging biodegradable. This means that the packaging when ended up in nature will degrade or that it can be industrially degraded and use to make for example biogas or mulch (Meerlanden, 2018). For the packaging to be industrially degraded, it must meet the EU criteria of EN 13432. These criteria need to be tested in a laboratory and are proven before the packaging receives the certification of biodegradable plastics (European Bioplastics, 2015):

1. A pilot composting test has been performed, and the packaging had lost a mass of 10% compared to the starting point of composting after three months.
2. 90% of biodegradation must be reached in less than 6 months, where the material is converted to CO2
3. There are no negative effects during the composting process
4. There should be no amount of heavy metals exceeding the maximum given values.

In addition to the industrially compostable certification, it is also possible for the packaging to be home composted, without all the special conditions provided in the industrial process. However, there is currently no international standard for home composting requirements (European Bioplastics, 2015). There are some national certifications for home composting in, for example, Belgium (European Bioplastics, 2015), but the Netherlands does not have it. For Miscanthus packaging, this means that for it to be certified compostable, it should have the EU certification and meets its criteria.

Food safe packaging

For packaging to be food-safe, it must receive the accompanying EU certification ((EC) 1935/2004). To receive this certification, the packaging must meet the following criteria (European Commissions, 2019):

- It does not release constituents into food which are harmful to human health
- It does not change the food composition, taste and odour

To meet these criteria, the packaging should receive a risk evaluation on what the possibility is of the packaging to not meet these criteria (Food Drink Europe, 2016). In the risk analysis, nature of the food, storage conditions, shelf life and packaging format are considered (Food Drink Europe, 2016). Functional barriers can be used to minimize this risk of not meeting one of the criteria, e.g.

applying a coating or laminate. A functional barrier is defined by the EU as an additional layer to the packaging that ensures the final material meets the EU 1935/2004 regulation for food safety. Packaging should be tested based on these criteria, using predefined tests (Food Drink Europe, 2016).

Using recycled paper increases the risk of mineral oils entering the food inside the packaging (Food Drink Europe, 2016). This is because mineral oils are used as an additive in newspaper inks. Some mineral oils are considered harmful to human health and should, therefore, be minimized when the paper comes in contact with food (Food Drink Europe, 2016). The Dutch government and the EU did not specify directly how many mineral oils are allowed in the packaging (PaperenKarton.nl, n.d).

To show the food safety of the packaging an eco-label must be shown (European Commissions, 2019) for consumers.

Conclusion

When looking at the regulations on European and local level, there are no specific regulations concerning Miscanthus as a crop. When a product will be developed based on Miscanthus, some laws and regulations will need to be considered. This means that for example for food packaging, the packaging needs to have certain certificates that it does not contain toxins that affect human food consumption. Besides, when the material needs specific barrier properties such as being waterproof, it also needs the right certificates. Lastly, the packaging needs to be certified to show it is biodegradable. Whenever one of these certificates are missing, it cannot be sold using the claim it is biodegradable for example. For the roadmap, it is important to determine when certain certifications need to be requested.

Also, there is an opportunity for packaging made from Miscanthus. It can become an alternative for single-use plastics or other packaging made from polluting resources. In this way, it can aid in reaching the Paris Agreement and be an alternative for the banned single-use packaging.

2.1.7 Sociocultural

The socio-cultural aspects look at the values, attitudes and behaviours in society (Mullins, Walker, Boyd, Larréché, 2013, p. 75). In this paragraph, the current attitude towards Miscanthus in society will be discussed. Furthermore, it will be investigated whether this has possible consequences when packaging made from Miscanthus will be introduced.

When determining the attitude of society towards Miscanthus, within the current literature, there is little to no information on the sociocultural effects of cultivating Miscanthus. Therefore, interviews have been conducted to complement the literature. An informal interview has been conducted with a fibre specialist from KCPK. In addition, an interview with a Miscanthus farmer in the Haarlemmermeer, has been conducted. Both interviews can be found in Appendix I & K respectively.

When looking at the attitude towards Miscanthus cultivation from the perspective of the government, there exists a fear that Miscanthus will have a negative effect on other native plant species that live in the Netherlands (Matthews, J. et al, 2015), the reason for this is that Miscanthus is not native to the Netherlands, as explained in Section 2.1.3. However, since Miscanthus is sterile, and does not proliferate, this is an ungrounded fear (Anderson et al, 2011). Another fear that could arise in society is the threat of Miscanthus replacing food production (Matthews et al, 2015). However, according to Matthews et al (2015), it is an unfounded fear that farmers will switch to growing Miscanthus when they already grow crops for food consumption in the Netherlands. In the Haarlemmermeer, the estimates are that Miscanthus cultivation will increase to around 2000 hectares (Personal communication, Van Elderen, H, 2019). This will mainly be regular farmland. Some test has been done to plant Miscanthus in the Haarlemmermeer on wasteland, however, these tests are stopped because of the improving economy in the Netherlands, these wasteland plots were being used for building sites (Personal communication, Adriaanse, M, 2019). Municipalities have difficulty with planting Miscanthus on wasteland for 25 years because it cannot be used for something else is this time.

Another socio-cultural aspect that needs to be taken into consideration when designing packaging is the disadvantage of Miscanthus having a long growth cycle. Farmers often make use of a crop rotation cycle (de Jong, personal communication, 16-4-2019; Elderen, van, personal communication,

2019; Adriaanse, personal communication). They divide their land into several areas and plant different crops on each plot. Each year, the farmer rotates the crops to another plot of land. In this way, the soil will not be depleted of nutrients. Due to the long-term growth cycle of Miscanthus, it does not fit the crop rotation cycle. It will stay on the same plot of land for at least 20 years. Farmers might be hesitant to plant a crop that does not fit their current crop rotation cycle. However, the problem of the soil being depleted of nutrients is not applicable for Miscanthus since it stores its nutrients in its roots (Lewandowski et al, 2000) only some nutrients get lost and according to Mathews et al (2015), it will not threaten food production.

When looking at the physiology of Miscanthus, people cannot see past a fully grown Miscanthus field because it grows between 3 and 4,5 meters high (Anderson et al, 2011). Therefore, people may perceive it as negative because it can block the view of for example homes that are standing next to Miscanthus fields. However, this is no different than the cultivation of other high growing crops such as corn.

Conclusion

When looking at packaging and cultivating Miscanthus, the socio-cultural aspects mainly involve the cultivation of Miscanthus. They do need to be considered when Miscanthus based products are being scaled up to higher production volumes. When this is the case, more land needs to be used for the cultivation of Miscanthus and then sociocultural aspects need to be taken into consideration.

2.2 Papermaking process

The scope of this project is creating packaging from Miscanthus based paper. To get a better understanding of the papermaking process and the opportunities it might provide, research has been done. This research consists of doing desk research in the existing literature and conducting informal interviews at KCPK. This paragraph will discuss the different steps of papermaking, the negative and positive (environmental) considerations and at last what papermaking of Miscanthus will uphold, for some background information a brief history of papermaking is added in Appendix F. Papermaking itself is a relatively simple process, however, it requires a lot of different steps which each can have multiple different options. Therefore, this information will provide the reader with relevant context about what steps are necessary to consider when developing paper packaging from Miscanthus.

2.2.1 Papermaking process and packaging production

Paper can be produced in three different ways. First of all, chemical pulping, this process consists of the cooking of the raw material (such as wood or Miscanthus) in chemicals, where the lignin is removed from the cellulose, leaving only the cellulose that can be used to make paper. The second option is mechanical pulping. This method consists of chopping the raw material mixed with water (sometimes under pressure or high heat), creating lignocellulose. In this case, the lignin is not removed but left in the paper pulp. It is also possible to combine mechanical and chemical pulping, however for this thesis they are considered as two separate processes. The third way of pulping is bio pulping, this is a relatively new technique where with the use of fungi, the lignin is extracted from the raw material, leaving only cellulose with a relatively low percentage of lignin. Biopulping is not implemented in industrial processes currently and is only relevant for the roadmap on the long term because there is still a lot that needs to be tested such as the effects of the bio pulping on Miscanthus. Appendix E discussed bio pulping in more detail. The visual (Figure 11) shows how paper and paper packaging is created by a step by step process, only looking at mechanical and chemical pulping since these two techniques are the most relevant for implementing Miscanthus based packaging.

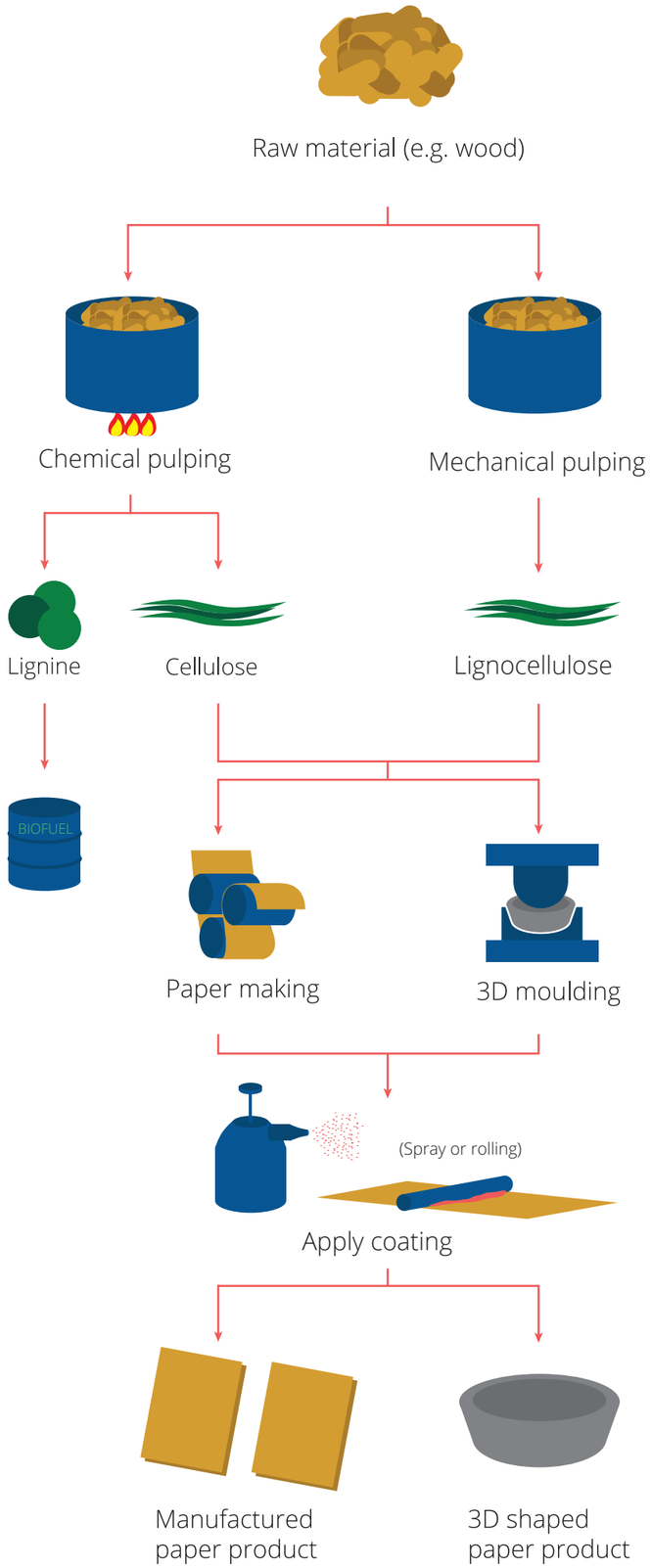


Figure 11: The papermaking process

The raw material (for example wood or Miscanthus) is chopped and treated. After that, the raw material will be cooked in chemicals or chopped with water mechanically to become paper pulp. With chemical pulping, not only the cellulose comes free, also lignin and other plant components can be extracted. With mechanical pulping, only the cellulose can be utilised. With the cellulose, paper can be made or 3D moulded products. By applying a coating, a final product is created that suits its purpose.

2.2.2 Paper making and quality

When looking at the difference between mechanical or chemical pulping of Miscanthus, there are both advantages and disadvantages. Table 3 describes for the different steps, the considerations that need to be taken int account when designing paper packaging from Miscanthus.

From the table, several differences can be seen. First, the main difference between mechanical and chemical pulping is the scale difference. Mechanical pulping can be a smaller scale while chemical pulping is only in large scale. For designing a Miscanthus packaging, this means that the batch size can affect the choice of production. Besides, there is a difference in quality. Chemical pulping has a higher quality but lower efficiency (more raw material necessary to produce x amount of paper pulp), while mechanical pulping has a lower quality but higher efficiency (less raw material necessary to produce x amount of paper pulp).

Table 3: Mechanical pulping versus chemical pulping

	Mechanical Pulping	Chemical pulping
Yield	Higher (~95%)	Medium (~60%)
Energy consumption	Higher	Lower
Chemicals	None	High
Paper quality	Medium	High
Appearance	Yellowish/brownish, rough surface	Whiter when bleached, smoother
Process conditions	Relatively mild	severe

2.2.3 Paper recycling

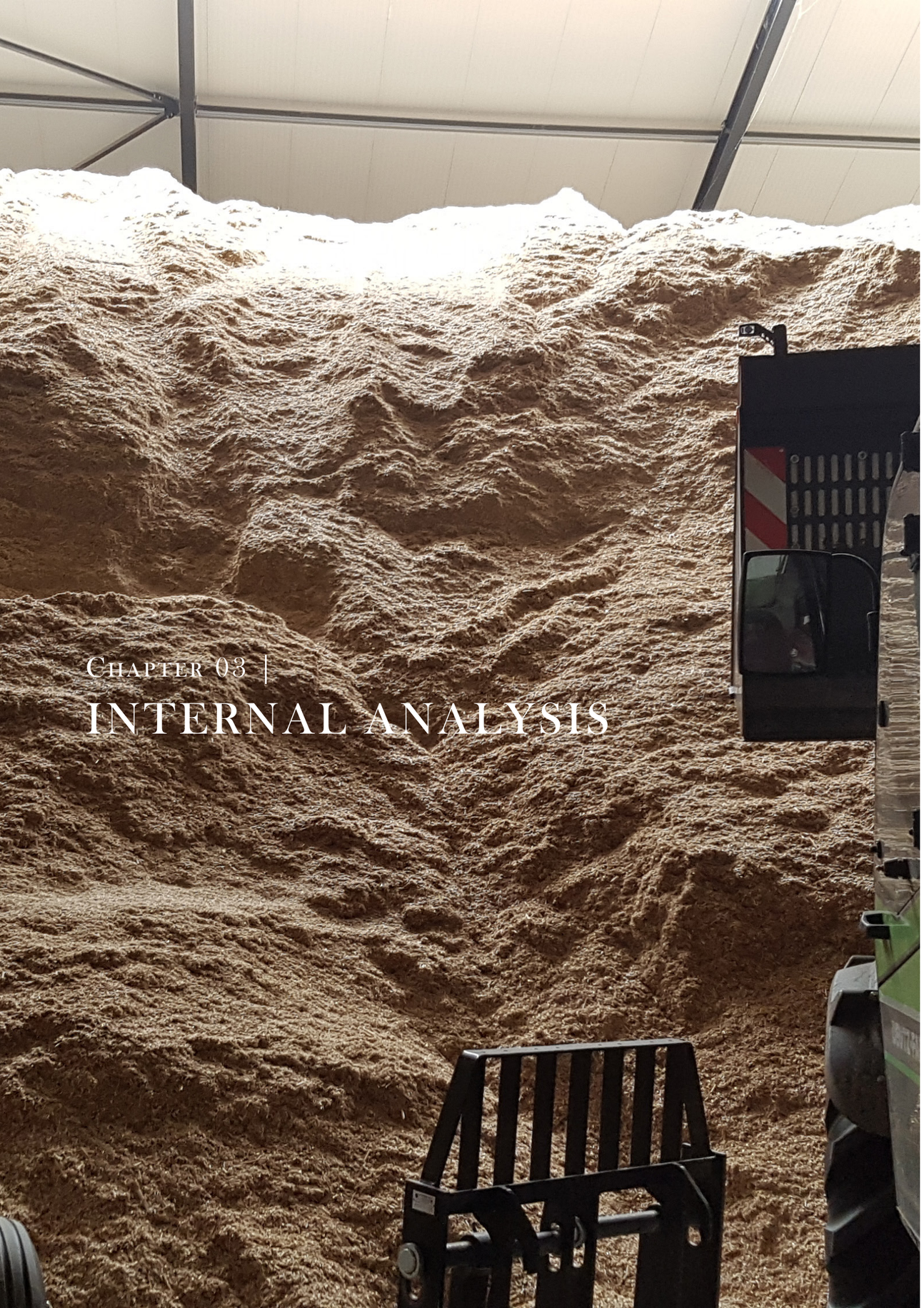
There are multiple ways that paper packaging can be cascaded, the different ways are determined by reading literature on paper recycling and by having an informal interview with a fibre specialist of KCPK. Table 4 compares the different cascading methods and the relevancy for Miscanthus packaging.
By comparing the different cascading methods, it shows that recycling Miscanthus fibres is the best way for Miscanthus packaging. The retrieved fibres can be used for new paper material and extend the use of the Miscanthus, fitting in the mindset of a circular economy. Additional to recycling, it is an opportunity to make Miscanthus packaging compostable or biodegradable, then when it ends up in nature, the packaging degrades on its own and it does not harm nature in any way.

Table 4: Different ways of cascading paper packaging.

Reuse of the packaging for another purpose	For Miscanthus based packaging this can be an option, however, to answer RQ1, the packaging will be a single-use and be possibly an alternative for single-use plastics.
Recycling of the fibres for new packaging	This is the most common way of paper recycling. The packaging will be separated from other ways, repulped and then manufactured to new packaging. For Miscanthus packaging this is a logical option because it has long fibres and can be recycled at least 5 times. This technique is also widely implemented for the current wastepaper streams.
Biodegradable	In order to retrieve the packaging, it is possible to make it biodegradable but the high grade Miscanthus fibres are lost in this case.
Compostable	This is similar to biodegradable. For Miscanthus packaging it is beneficial to be compostable but not a main priority because it the fibres can be recycled easily, reducing the amount of virgin fibres needed.
As an energy source	Using wastepaper as an energy source is possible, but again the high grade Miscanthus fibres are lost in this case and cannot be retrieved. Therefore, incinerating Miscanthus packaging is not beneficial.

2.2.4 Conclusion

For Miscanthus paper, the production process of papermaking can influence the outcome of this thesis, the later designed design artefacts will explore the different design paths that can be taken when chosen either mechanical pulping or chemical pulping. From the Elgra perspective, they find it important that the packaging will have the life cycle that has the lowest possible environmental impact, on a system level. However, having the lowest environmental impact is not necessarily the best option to go for in terms of the production process. Other aspects need to be considered, such as but not limited to batch size, costs and transport. These considerations will be made in the further design phase of this thesis.



Chapter 03 |

INTERNAL ANALYSIS

3.1 Company Analysis

To get a better understanding of the context of this project, a company analysis is done. In this company analysis, both KCPK and Elgra will be discussed. Within the company analysis, several aspects of both companies are analysed such as the company structure, the resources, the capabilities, the core competencies and sustainable competitive advantage. This is done to look at the broader aspect of both companies and to get a better understanding of its aspects that can be used further in the project. Knowing the resources and capabilities of both companies for the foundation for the strategy and from there can be determined what aspects need to be added to have a strong market positioning. For KCPK, the sustainable competitive advantage is left out of the analysis because it is not relevant for answering the research questions since these are about specifically Miscanthus packaging and the sustainable competitive advantage of KCPK looks at how KCPK operates in the market as a company related to their competition in the paper industry as a whole.

3.1.1 KCPK

KCPK is a non-profit organisation that focusses mainly on generating knowledge and disseminating that to companies operating in the paper industry (Kenniscentrum Papier en Karton, 2019). KCPK operates under the umbrella of the Dutch trade organisation of the paper industry. They are situated in Arnhem, the Netherlands.

KCPK has structured the company by using three different business units. These business units are Fibre Raw Materials, Technology and Process, and End Products. Figure 12 shows a visual representation of the three business units.

Fibre raw materials

Within the paper industry, fibres are the main resource for production. Commonly, the paper is made from tree fibres, however, the Netherlands has a long history of using plant fibres to produce paper and board. To create paper and board, the quality of the fibre is of great importance, since this will have an impact on the quality of the paper and the recyclability. This business unit looks at raw fibres and future availability of these fibres and, examines the quality of the fibres.

Technology & process

The second business unit Technology and Process focus on the optimisation of production processes and the increase of energy efficiency. Within the paper industry, there already has been a lot of improvements to have CO2 reduction within its production processes, such as using lignin for powering the production plants instead of grey power. At KCPK they investigate the technological innovations and how these can be used to optimise the current production facilities.

End products

The third business unit is End products. This division of the company looks at the value chain of paper and board and the final products made from it. They look at what trends are happening within the market and how paper-based products can play a role within these trends. KCPK helps Dutch paper and board companies to strengthen their competitive advantage in the paper industry by providing them with opportunities for new materials or products. Therefore, this platform is also operating on an international level.

For KCPK it is important to know the possibilities of Miscanthus fibres. This project falls under the platform End Products. For this department, it is relevant because this thesis will look at the product life cycle of Miscanthus based paper products and the implementation of it in the market. This thesis can contribute to this department by researching the possibilities of packaging made from Miscanthus and the possibilities for it being implemented using a circular model.

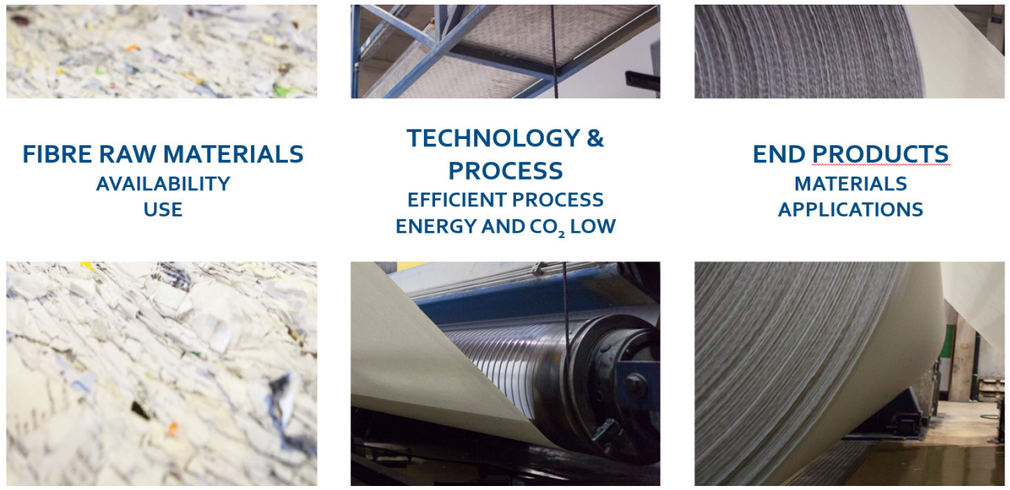


Figure 12: Business units of KCPK (internal communication, 2019)

Resources

The resources of KCPK are mainly knowledge-based. As a core business, they focus on four different aspects:

Scan

KCPK works closely together with academics and research institutes to scan the market for innovations relevant to the paper industry.

Scout

Technical developments outside of the sector are also monitored to supplement their knowledge for the paper and board industry.

Study

By studying the knowledge gained from the industry and the projects they manage, roadmaps are formulated that show developments and the user needs from the sector.

Collaborate

KCPK has collaborations with the different players in the paper and board industry, divided over five platforms: Fibre Raw Materials, Technology & Process, End Products, Water, and Technical Services.

These different activities are summarised in the mission of KCPK, which is as follows:

KCPK aims to bridge the gap between fundamental research and market adoption by focussing all its activities towards technology and product development and implementation in the paper and board industry.

This thesis fits within this mission because it researches the possibilities of a paper product made from an alternative fibre, in this case, Miscanthus. Furthermore, this thesis will also look at how this can be put into a circular model and the implementation in the industry, which also fits the mission of KCPK.

Capabilities

The capabilities of KCPK can be described in two different aspects. On the one hand hard capabilities, which are the skills they are capable of and on the other hand soft capabilities, which are the drives and motives of the company.

Hard capabilities

KCPK has a broad network throughout the paper industry. They are connected to the VNP, the Dutch trade association of the paper industry. Figure 13 shows the members of paper and board companies that KCPK has in the Netherlands. They have close collaborations with all the companies shown in this visual.

In addition to having a broad network and finding more members, they also own a laboratory where they can test innovations from the paper and board industry (KCPK, 2019). This laboratory is situated close to Arnhem and members of KPCK can use this for their experiments.

Soft capabilities

Within KCPK, sustainability and circular economy are of great importance. Many innovations are regarding one of these two topics. The soft capabilities KCPK, are therefore the intrinsic motivation of making the paper industry more sustainable.

Besides, the employees of KCPK are great connectors. They know their network and who to speak with and use these soft skills to gain more knowledge and connect people who have innovations.

Core competencies

The core competencies look at what the organisation distinguishes itself from other companies (Investopedia, 2019). Since KCPK is the only knowledge centre of paper and board in the Netherlands, they do not have to distinguish themselves from other companies. However, they do need to be aware of companies that are working on paper and board innovations to keep their knowledge up to date. Also, other institutes work on similar topics such as the knowledge institute of sustainable packaging (KIDV) (KIDV, 2019). Who specifically focus on sustainable packaging. There is overlap in the activities of both KCPK and KIDV, where KCPK places the focus more on paper-based packaging and KIDV looks at the broader range of sustainable packaging.

Figure 13: Member of KCPK

3.1.2 Elgra

The company that cultivates Miscanthus and aims to be producing Miscanthus based packaging is called Elgra. The company is still small with only two employees, Gertjan de Jong and John Eirhard. It consists out of three separate divisions, operating under the name Elgra. The three separate divisions are MISQ, Miscanthusgroep Haarlemmermeer and a yet to be named financial department. This structure is chosen for to eliminate the risk of personal bankruptcy. Figure 14 shows the company structure.

Resources

Elgra itself has not many resources. They do not own an office (yet) and all funding comes from subsidies and private investments. Concerning the financial resources, some income is generated from the sales of Miscanthus to other companies that manufacture products based on Miscanthus, current applications are;

- Concrete enforced with Miscanthus fibres: used for sound walls and bicycle paths
- Flooring for riding school stables and petting zoos
- Bedding for festivals to absorb moist to prevent the terrain from becoming muddy
- Composites
- Roof isolation
- Garden mulch
- Animal feed factory as additional nutrients for animals
- Tree plantations as soil

Capabilities

Capabilities of Elgra can be divided into two different categories, hard and soft capabilities. Hard capabilities look at the processes and manufacturing capabilities of the company and soft capabilities look at the values and qualities of a company, this can be for example the strategic implementation, collaborations and marketing strategies.

Soft capabilities

Within Elgra, there is always a drive for sustainability. There is a lot of knowledge about sustainability and they want to reduce CO2 emissions.

Hard capabilities

Within the division Miscanthusgroep Haarlemmermeer, the farmers that cultivate Miscanthus are situated. They have contacts with several parties that buy Miscanthus. The farmers are also responsible for the growth and harvest of it. Besides, Miscanthusgroep Haarlemmermeer also chops the Miscanthus plants to the right size for every application they currently sell.

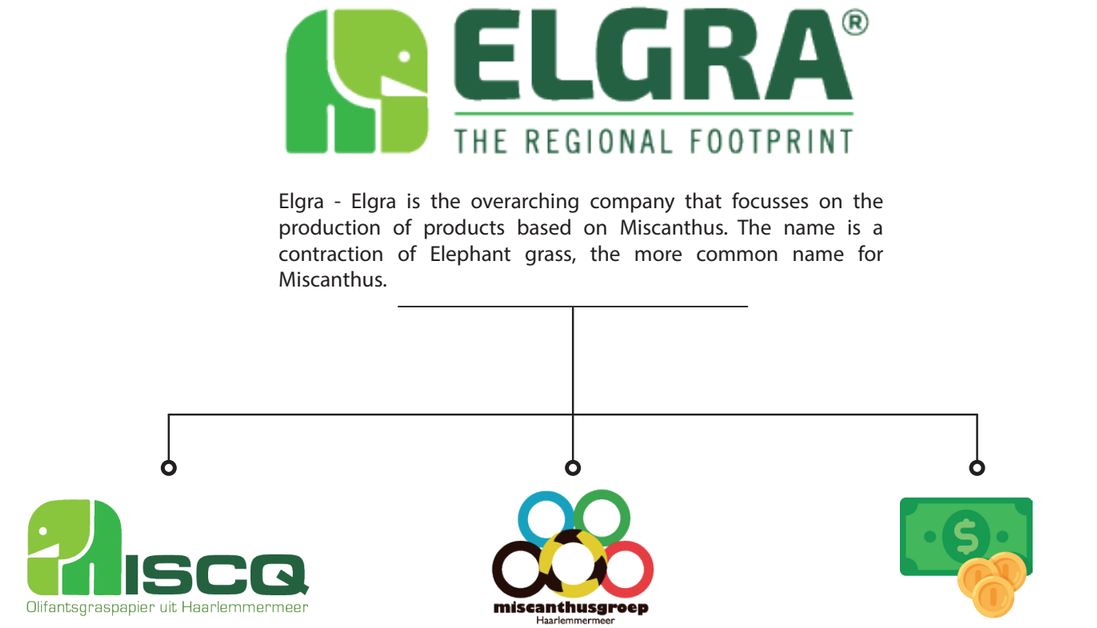


Figure 14: Elgra company structure

Hard capabilities, therefore, are the ability to cultivate and sell Miscanthus.

Soon, Elgra is planning to build a facility to create Miscanthus based paper products. In this thesis, this will be added to the roadmap and the path towards building a factory will be evaluated.

Core competencies

The core competencies look at how the company distinguishes itself from other companies with their current capabilities. The hard and soft capabilities only describe what Elgra is doing, the competencies put this into perspective on the market. For Elgra this means that they are one of the few (soon to be) manufacturing companies that also cultivate their Miscanthus for production of Miscanthus based packaging. In Section 4.1.1, this is further discussed. This helps them because they can also deliver raw materials to other companies but still have enough resources for their production. By producing their raw materials and being one of the few companies that cultivate Miscanthus, it is not easy for competitors to imitate this because acquiring necessary resources such as farmland and knowledge of Miscanthus cultivation is difficult to acquire. When looking at potential customers, Elgra is situated around the airport of Schiphol, this is also the same area where they cultivate Miscanthus. This provides opportunities to provide solutions for the airport industry in the form of packaging or other products that can help in making the airport circular. However, it still needs to be tested whether there is a mutual benefit for Schiphol as well in addition to the circular packaging.

Sustainable competitive advantage

When looking at the sustainable competitive advantage of Elgra, there are a few things to consider. Currently, Elgra has already some products that are sold that do not necessarily compete in price but do compete in value and serve a specific niche market. For example, Elgra sells Miscanthus to a concrete manufacturer that uses it for reinforcement instead of steel. This results in a strong concreate which has a lower environmental impact compared to steel reinforced concrete. However, the market for Miscanthus concrete is still relatively small and is currently only used for prestige projects of municipalities to show a cleaner alternative for concrete in the build environment. This strategy helps in gaining competitive advantage. Currently, they are one of the few companies that supply Miscanthus products (chopped Miscanthus) to other companies that create products out of it, this is further discussed in the competitor analysis in Section XX. The value advantage is that the aim is to reduce the CO_2 footprint. This is done by using Miscanthus in concrete instead of steel for reinforcement. This is still a niche market with little competition. Since Elgra does not have a lot of capital, for future products made from Miscanthus, it is difficult to compete based on price. Price competitive advantage mostly comes by selling a lot of products to a broad market which is not possible for Miscanthus based products (yet). For Elgra at the beginning most competitive advantage can be gained by focussing on the added value of Miscanthus based paper products to a certain (niche) market, this needs to be considered in further development processes.

CHAPTER 04

EXTERNAL ANALYSIS

4.1 INDUSTRY FORCES

This chapter describes what is happening in the industry within the context of Miscanthus and the competitive environment of (sustainable) packaging. It contains two topics: (incumbent) competition and substitute products. Both topics combined, indicate the forces happening in the industry and is relevant for answering RQ2 (*How to position a new type of sustainable packaging made from Miscanthus on an existing market?*) by considering the industry in positioning a new sustainable packaging made from Miscanthus on the market.

4.1.1 Competition

The competition analysis has the focus on various companies that compete with Elgra. The competition of KCPK is in this case less relevant because they will not be bringing sustainable packaging made from Miscanthus on the market. The different competitors are divided into two different categories. These categories are:

- Miscanthus related competition: this kind of competition sells products made from Miscanthus.
- Alternative for single-use plastics: This competition sells and manufactures products made from sustainable materials as an alternative for single-use plastics (e.g. disposables).

These categories are chosen to get a broad perspective about what is happening in the market in terms of competition.

Miscanthus related competition

The first type of competition is defined as companies that produce (packaging) products made from Miscanthus. In this category, there are two different types of companies. The first company that is looked at, is a company that manufactures consumer products made from Miscanthus fibres. The second type of companies are manufacturers of Miscanthus based paper. The selection for the companies that fall into this category are active in the Netherlands, and therefore a direct competition for Elgra when they launch their first Miscanthus based packaging in the market, and they produce and sell Miscanthus based packaging/products.

Alternative for single-use plastic competition

For the second type of competition, companies that sell alternatives for single-use plastic competition are examined. The selection of the companies discussed is based on that they operate in the Netherlands, have a large product range (Biofutura and Huhtamaki) or a unique product (Paperwise). In this category, there are a lot more companies that have a similar business model, however, these three are currently the largest and are the strongest competition for Elgra because of their size and product offering.

Conclusion

The companies CradleCrops, Schutpapier and Miscancell are mostly companies that cultivate Miscanthus or produce Miscanthus based paper products. When designing a product for Miscanthus, it needs to be considered that the companies in this category are also looking for product opportunities. A possibility would be collaborating with them, to combine the research done on Miscanthus based products. However, when this is not the case, they could be a threat to Elgra since they are larger well-established companies that own more capital and can make therefore bigger investments. Elgra could overcome this by establishing collaborations with partners in the product life cycle such as waste managers, production facilities and R&D consultancies. Besides, the local for local aspect is still a product opportunity for Elgra which is unique compared to the described competitors.

In addition, there are many more similar companies that have similar motives and values as the companies described in the alternative for single-use plastic category. These companies are for example Greenbox Netherlands, Bio4pack and RajaPack. These companies all sell sustainable packaging which are alternatives from single-use plastic and is not chosen to examine because they offer the same products as Biofutura. Most packaging types that are being sold at these companies are biodegradable. A difficulty for these types of packaging is that consumer might not know that the packaging can be thrown away in the green waste bin, this insight came from the expert interviews conducted (Appendix O, P, Q). Also, the products sold by these companies are not introduced in a closed system, and therefore are (mostly) not collected and recycled. For Miscanthus based packaging it can be an opportunity to have a packaging that is collected and recycled into new types of packaging to not lose the cellulose by composting it.

COMPETITOR ANALYSIS

The visual shows two different type of competition. One is the Miscanthus related compatition, the other is the Alternative for single-use plastic competition. Each competitor has been analysed by using literature and some company interviews. This visual shows a short conclusion of the companies. The conclusion of the anaysis can be found on the next pace. The full competitor analysis can be found in appendix J.

Miscanthus related competition

Alternative for single-use plastic competition

ELGRA®
THE REGIONAL FOOTPRINT

vibers

Vibers is currently the only company in the Netherlands that produces and sells products based on Miscanthus such as trays, paper and board. They offer a wide range of products which are already fully developed. This could be a threat for Elgra since they are a lot further in their development stage. In addition, for packaging made from Miscanthus, this means that it should have a differentiating position by being able for example to be recycled at the green waste stream or fits within a circular business model.

Schutpapier might be a potential partner for packaging made form Miscanthus since they create paper sheets from alternative fibres as well. However, this might be difficult as well because of their collaboration with Vibers. Although this collaboration, there is still a possibility for Elgra to work with Schut papier since they are a large manufacturer of paper based on alternative fibres.

SCHUT PAPIER
400 jaar
PASSION · CRAFTSMANSHIP · DEVELOPMENT

Cradle-Crops

There is a low influence of Cradle Crops when packaging is manufactured from Miscanthus. Currently, they operate in a different demographic area, are not local for local (the paper manufacturing plant is in Swalmen, Limburg) and are focussed on producing sanitary towels in collaboration with Wepa which is a different branch of paper production also requiring different production methods so not comparable to packaging.

Currently, there is a low influence on sustainable packaging made from Miscanthus by Elgra. Miscancell is not active (anymore) and does not sell products made from Miscanthus. However, because of their collaboration with BKC, it can be a threat to Elgra since they do not have such a collaboration.

miscancell

Huhtamaki

For Elgra, Huhtamaki can be a strong competitor when looking at their developments of sustainable packaging. From the product categories can be seen that Huhtamaki produces a large range of products, however not only sustainable packaging. In addition, they do not have a product made from Miscanthus. Huhtamaki can be a possible collaboration for the production of Miscanthus based packaging, they have the facilities and the capital to make investments.

PAPER WISE
WISE WITH WASTE

Paperwise will have a moderate influence on sustainable packaging made from Miscanthus. During an interview with the CEO of Paperwise, it became clear that they believe that products should not be made with virgin (newly produced) materials but should use existing waste streams. In addition, Paperwise has already created a strong brand concerning sustainable packaging and might be a treat to Miscanthus based packaging when this is introduced on the market.

biofutura

For packaging made from Miscanthus, the company itself has a low influence. However, when a collaboration is initiated, Biofutura could be a potential reseller of the Miscanthus products to reach a broader audience. The company does give a good indication on prices of other sustainable packaging products that might be of interest later in the project. From the cost structure can be seen that products made from PLA are relatively cheaper than the same product made from for example palm leaf or sugarcane.

4.1.2 Substitute products

From the competitor analysis, it can be concluded that more companies are focussing developing sustainable packaging. Next, to companies entering the market with single-use plastic alternatives, there are also developments concerning different materials that can be used to develop sustainable packaging. To form a complete picture of the industry forces and to help in answering RQ2 (*How to position a new type of sustainable packaging made from Miscanthus on an existing market?*), it is important to know what other materials are emerging. This paragraph will look at what materials are currently available and how Miscanthus can substitute these materials. This analysis is not a benchmark of the existing situation but looks at emerging sustainable packaging material. This is done because it will indicate the forces and developments of the industry of sustainable packaging. Learnings from this analysis can be used to give Miscanthus based packaging a unique and stronger positioning in the market and make clear how to differentiate it from existing materials.

Method

This analysis will look at the possibility for companies to switch from plastic to these materials and if Miscanthus paper is a possibility for that. Costs are also an important factor for being a substitute packaging material, this is not included in this analysis.

In addition to the analysis of the material, also design qualities are considered such as look and feel and appearance. Since the aim is to reduce plastic waste, regular plastic is not included in this analysis. All materials in this analysis are sustainable alternatives to single-use plastic but are not necessarily biodegradable. This is important to mention because non-biodegradable packaging, often still has the potential to become circular by recycling. For the material alternatives, ten different alternatives are identified by doing a literature review on what new emerging materials there are in the packaging sector.

To compare the different materials, they are categorised in two different categories. These categories are (bio) plastic materials, which resemble plastic and have similar material properties, and paper-based materials, which resemble paper or cellulose-based materials and have similar material properties compared to Miscanthus based packaging. This categorisation is chosen to able to compare the different materials to each other since plastic-like materials have often different functionalities than paper-like materials. Plastic like materials are often transparent and require a different production method compare to cellulose-based materials. This difference in production method has also an influence on how easy it is for companies to switch to another material or not.

For each category, a selection has been made of the most interesting materials, verified by an end-product specialist of KCPK and commissioner of this thesis. The chosen materials are gaining more interest by companies and developers and are emerging in the market of sustainable packaging. A visualisation and comparison of the different materials can be seen on page 63 & 64.

Discussion

From the analysed materials, several are marked as likely to substituted by Miscanthus based packaging, these are:

- Bagasse,
- Palm leaves,
- Recycled paper
- PLA,
- Hemp,
- Recycled plastic

Reasons for this are that the materials are versatile and can be used in many different forms. The largest threat for Miscanthus based packaging is recycled paper, hemp and PLA. For plastic manufacturers, PLA is a logical switch because it requires similar machinery. For paper manufacturers, recycled paper and hemp are logical choices because they require little to no change to the current equipment. Besides, recycled paper has already a large infrastructure in place and a large amount of current paper packaging is already recycled. Hemp is a versatile crop that is already present in different market segments such as clothing, rope making, bioplastic and paper. Because of its versatility, a business model can be created that utilises hemp in many forms. A disadvantage of hemp is the difficulty of cultivation in the Netherlands, currently, there is only one harvesting machine in the Netherlands, capable of harvesting hemp (Elderen, van, personal communication, 2019). In addition, hemp is because of its sturdiness difficult to process, a lot of additional energy is needed to refine hemp to its final form compared to the energy needed to process Miscanthus (Elderen, van, personal communication, 2019). Miscanthus can be harvested using a regular corn harvesting machine which is more common in the Netherlands therefore, less investment is needed. In addition, there are also sociocultural disadvantages to cultivating hemp, Miscanthus farmer Hein van Elderen had previously cultivated hemp

MISCANTHUS

Application

Packaging. Replacement for single-use plastics.

Feel & Appearance

Paper like material. On the outside a rough surface. Interesting material. Sustainable looking.

(Dis)advantages

+ Locally cultivated and produced
+ Potential to be carbon neutral packaging
+ Easy grown crop, not invasive (sterile)
+ Perceived as sustainable

- Not yet fully developed
- Brittle material
- Looks familiar, not unique

MYCELIUM

Application

Resemble paper, rubber, plastic and wooden products. Replaces foam packaging.

Feel & Appearance

White, foam like and velvety.
Not translucent. No odour. Has a texture. Resilient. Warm touch.

(Dis)advantages

+ Mushroom roots grow in the right shape
+ Cradle to cradle certified

- Still in development phase
- Not widely implemented

Substitute Miscanthus packaging

This material is a foam like material and Miscanthus is **not likely** to substitute this material. The material is thick and not suitable for carboard like packaging. In addition, manufacturing Mycelium packaging requires specific machinery, not widely available. Its application purpose is also different compared to Miscanthus based sustainable packaging.

BAGASSE

Application

Plates, cups, bowls and packaging.

Feel & Appearance

Like polystyrene. Products can be white or brown, depending on the manufacturing process. Paper like material. Smooth surface. Can be coloured.

(Dis)advantages

+ By-product of sugarcane industry, waste management
+ Widely implemented
+ Compostable

- Only simple shapes
- Additives needed to make material

Substitute Miscanthus packaging

Miscanthus is **likely** to substitute Bagasse based packaging, since it has similar properties. Bagasse is a thin material that is moulded to the right shape, like Miscanthus packaging. However, the raw material does need to be imported from abroad to the Netherlands to be manufactured here, while Miscanthus grows and can be manufactured locally.

STONE PAPER

Application

Used to make paper products using components found in stone (calcium carbonate).

Feel & Appearance

White material. No grain. Tear resistance.

(Dis)advantages

+ Waterproof
+ Durable

- Degrades in sunlight
- Uses HDPE, which is not always recyclable
- only flat surfaces been made until now

Substitute Miscanthus packaging

Miscanthus is **not likely** to substitute Stone Paper based packaging. It resembles printing paper and not packaging, also it cannot be moulded to a 3D shape. In addition, it does make use of an additive HDPE, which makes it not completely fossil material free.

PALM LEAVES

Application

Palm leaves are used to create bowls and plates.

Feel & Appearance

Brown colour can be either pressed as a plate with a smooth surface. Or braided into a basked. The grain of the leaves is visible.

(Dis)advantages

+ Hard material
+ No chemicals or coating

- Only semi flat products
- Grooves get dirty when used and hard to clean

Substitute Miscanthus packaging

Miscanthus is **likely** to substitute Palm leaves because they both are versatile and biodegradable. Palm leaves can be moulded into 3D shapes (packaging) or used in it natural form as packaging. Therefore, it has similar properties compared to Miscanthus based packaging. However, it does not naturally grow in the Netherlands so it must be imported, resulting in a larger footprint.

PAPER FOAM

Application

Packaging for protection of consumer goods.

Feel & Appearance

Foam like material, not translucent. Multiple colours, mostly white. Smooth surface.

(Dis)advantages

+ Replaces Styrofoam packaging
+ Made of potato starch, bio based
+ Anti-static

- Not water-resistant
- Production cost price is higher than other types of packaging

Substitute Miscanthus packaging

Miscanthus is **not likely** to substitute Paperfoam because it serves a different purpose. Paperfoam is mainly used as protective material for consumer electronics where Miscanthus currently not suitable for. The material is thick and soft, suitable for its purpose.

RECYCLED PAPER

Application

All kinds of paper-based products such as cups, bags and cutlery.

Feel & Appearance

All kinds of paper-based products such as cups, bags and cutlery.

(Dis)advantages

+ Less new material needed
+ Easy to manufacturing with existing machines

- Often contaminated due to previous use
- Needs to be collected by the consumer

Substitute Miscanthus packaging

Miscanthus is **likely** to substitute old paper and board. For old paper and board is already an infrastructure in place to manufacture it. Miscanthus based paper can use this existing infrastructure. In a closed system gradually replacing paper and board recycling streams.

PLA

Application

Cups, cutlery, waste bags.

Feel & Appearance

Smooth material. Often clear but can also be opaque. Can have logos printed on.

(Dis)advantages

+ Same look and feel as plastic
+ Sustainable source (corn starge)

- Cannot withstand heat
- Brittle material

Substitute Miscanthus packaging

Miscanthus is **likely** to substitute PLA. PLA is similar to plastic and has many different applications. However, it is not fully biodegradable (only industrial), and is not a strong material. Miscanthus based packaging is tougher and biodegrable when manufactured with the right additives.

SEAWEED

Application

Sachets and wraps.

Feel & Appearance

Plastic like, opaque material.

(Dis)advantages

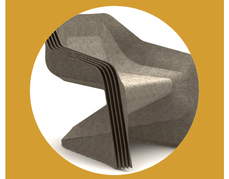
+ Edible
+ Can be heat pressed

- No mature market
- Ruptures quickly

Substitute Miscanthus packaging

Miscanthus is **not likely** to substitute Seaweed. Seaweed is mainly used for food wraps that are edible. Seaweed is a thin material that is made into a film. This has different applications compared to Miscanthus based packaging.

HEMP



Application

Fabric for clothes, rope, when pressed it can be moulded to a stiff material. Bioplastic.

Feel & Appearance

Brown, rough material.

(Dis)advantages

+ Versatile
+ Strong bioplastic

- Fabric is often mixed with cotton
- Bioplastic industry is still limited
- Difficult to cultivate

Substitute Miscanthus packaging

Miscanthus is **likely** to substitute Hemp because it is versatile and can be used for many different applications. Hemp can be used to create bioplastic but also as a cellulose to create packaging. However, it is difficult to cultivate by farmers because special equipment is needed for harvesting. In addition, hemp not widely available at the moment.

RECYCLED PLASTIC

Application

All kind of products which are now made of new plastic but then made from recycled plastic.

Feel & Appearance

Can be a fabric or normal plastic. Smooth finish.

(Dis)advantages

+ Recycle existing material
+ Same form freedom as existing plastic

- Still fossil based
- Still possible polluting the natural environment

Substitute Miscanthus packaging

Miscanthus is **likely** to substitute recycled plastic because recycled plastic is versatile and similar to regular (single-use) plastic packaging. However, it is still fossil based and not biodegradable. In addition, a lot of plastics are still not being recycled or cannot be recycled.


MENNENS BONGEN

as well and at multiple occasions, parts of his crops were stolen because people believed they could smoke it (as looks like cannabis). Industrial hemp is however not the same kind used for cannabis production and cannot be smoked. As for PLA, this is the industrially biodegradable alternative for single-use plastics made from a renewable source (mostly corn starch). Because of its resemblance to regular plastics, it is relatively easy to replace it. Although, it melts at relatively low temperatures (100 – 140 °C), therefore it is not suitable for example for containing hot liquids.

When looking at Miscanthus based packaging, it is important to consider potential substitute materials. For companies to switch to alternative materials (either manufacturing or packaging for their products) requires research and investment. This applies to all sustainable materials, including Miscanthus. To ensure a strong market positioning, for Miscanthus, the weaknesses of recycled paper and hemp can be used to strengthen the position of Miscanthus based packaging to create a convincing market positioning. However, when looking at the roadmap, including hemp and recycled paper in the business model can be interesting to look at since recycled paper is already widely implemented and hemp can be additional to Miscanthus because of its many possibilities such as clothing, paper or bioplastics..

4.1.3 Circular business models

This thesis aims to create a circular innovation strategy. Together with this, also a circular business model needs to be formulated, to make the strategy feasible. A business model is defined as a way for a firm to create an appropriate economic value (Osterwalder & Pigneur, 2010). This is made circular by having the aim of not depleting the world's resources to make the business model valid. There are different types of circular business models, depending on the market and the product category, a certain circular business model might be fitting for Elgra or not. This section discusses the first five different circular business models defined by Accenture (2014) (a large strategic consultancy firm), who researched 120 case studies that operate under a circular model. The reason to choose the circular business models defined by Accenture is that their research is known for the extensiveness and they cover five different aspects that can be used to define a potential business model for Miscanthus based packaging. After describing the circular business models, this section evaluates which of these five strategies best fits for Elgra and concludes with some example cases of companies that make use of these business models.

Table XX describes the five different circular business models by Accenture (2014) and discusses the relevancy for Elgra and Miscanthus based packaging.

Business model	Description	Relevancy for Elgra
1. Circular supplies	Providing fully renewable, recyclable or biodegradable energy. Most powerful for companies that have scarce commodities or with a large environmental footprint. (Accenture, 2014)	This business model is fully focussed on providing renewable energy. For Miscanthus this can be an opportunity to be used as a biofuel. Miscanthus has a high lignin content (Section XX) which is beneficial for heat production. However, when Miscanthus is being burned, the cellulose is lost, and it cannot be used for paper making.
2. Resource Recovery	Recovery of goods at the end of a product life cycle and use this for another new product, transforming waste into value through recycling. Among this, are closed loops recycling and cradle to cradle design. This model fits companies that produce large volumes of a by-product or where waste products can be retrieved and reprocessed. (Accenture, 2014)	For Elgra, this business model can be interesting. Miscanthus based packaging is expected to have a large volume to lower the price per piece, therefore introducing Miscanthus in a closed loop system means it can be retrieved and similar to regular paper, be recycled.
3. Product life cycle extension	The goal of this business model is to extend the product life cycle by repairing, upgrading, remanufacturing or remarketing products. This business model is suitable for B2B companies with large industrial equipment or B2C companies that sell for example modular products. (Accenture, 2014)	For Elgra, this business model is not suitable because Miscanthus based packaging is presumable not a product with multiple components that can be repaired. Since Miscanthus based packaging is assumed to be easily recycled, repairing it is not a logical way to go.
4. Sharing Platforms	This business model is about creating a platform that facilitates collaboration between users. This business model fits companies that sell products that have a low ownership rate, of platform companies that enables users to share products (Accenture, 2014).	This business model is not suitable for Miscanthus based packaging since most packaging is only for single-use. In addition, most of the time, packaging does not spark ownership with users and is product specific. Sharing packaging with other users is therefore assumed not to be useful.
5. Products as a service	This business model is about leasing or pay-per-use a product. The longevity, reusability and sharing are drivers for revenues and reduce costs. This business model is suitable for companies that have high operation costs and benefit from being maintained by the company itself. (Accenture, 2014)	For Elgra, this business model is not suitable because Miscanthus based packaging is mainly for single-use. Therefore leasing and maintaining it is not possible.

From the analysis can be concluded that only the circular business model type “circular supplies” and “Resource recovery” are relevant for Elgra. When looking at the scope of this thesis, which is about Miscanthus based packaging, only the business model “Resource recovery” is relevant because it focusses on recovering waste material in a closed loop system which provides an opportunity for Miscanthus based packaging. Especially in a local for local context, introducing Miscanthus packaging can be beneficial in a closed loop system because it can be produced, used, collected and remanufactured in a new Miscanthus based packaging locally.

To investigate the Resource Recovery business model further, two different example cases are reviewed. The first example case is Kartent, the second collection programs for coffee cups. These two cases are chosen because they illustrate a closed loop business model and potential advantages and pitfalls can be uncovered. There are more similar companies that can be investigated, however, within KCPK there are already connections with Kartent which provided the opportunity for a company visit and an interview with one of the directors of the company.

Takeaways for Miscanthus based material

Important takeaways from Kartent (full analysis in Appendix L) is the advantage of having a closed system. Because the tents are distributed and collected again by Kartent themselves, they can be remanufactured for another purpose after use. It does require a logistics infrastructure to do this. Besides, the price is an important factor for consumers to choose the sustainable alternative, it is important to keep the price attractive for the right consumer. In the case of festivals and Kartent, this means the price should be low to compete with cheap disposable tents.

Another takeaway is the collaboration of Kartent and the cardboard manufacturer. From the interview it became clear that they had a close collaboration and developed the tent together, making use of the human-centred thinking of the designers and the technical specialism of the paper manufacturer. In addition, having a product that can have multiple functionalities before reaching end-of-life and being discarded can have great value concerning a circular innovation strategy. By bringing the product (or in this case material) back to the consumer in a different form can have an advantage for the business model and decreases the need for new products.

Collection programs

When looking at the currently existing circular models on the market, the collection programs of coffee cups is interesting to look at because it is already widely implemented, and the system can be an example of how Miscanthus based packaging can be distributed and collected again. At a lot of different organisations where paper (or plastic) coffee cups are used, there are also collection programs in place to collect the cups and to recycle them. Within the market, several companies offer collection programs for these cups. The companies that offer these services, often provide their customers with a way of collecting the cups such as a special bag or box where employees can dispose. When the cups are collected, they are recycled to new paper products. The waste manager Renewi offers a collection program for coffee cups, this has been examined as an example company, the full analysis can be found in Appendix L.

Takeaways for Miscanthus based material

Renewi offers a service that makes use of a collaboration between Renewi and WEPA. Having a collaboration with a paper manufacturer gives the advantage of joining forces and creating new products from waste streams (in this case paper coffee cups). Similar to Kartent, this is also a closed system, meaning that the cups are only used within the office building where they are collected in a separate waste stream to be recycled to a different product.

4.2 Trend analysis

To get a better understanding of the context of sustainable packaging and the developments in the industry, a trend analysis is conducted. This trend analysis will use the DEPEST-method which identifies six domains for trends. Each domain looks at society from a different angle. To answer the research questions formulated in Section 1.2 it is relevant to know what is happening in the market now and in the future, a trend analysis can answer this question. The insight from this analysis will be used in the SWOT analysis, presented at the end of this chapter that concludes all the results of the analysis that is done. It helps in finding relevant and interesting market opportunities. The visual on the next page shows the results of the trend analysis. A lot more trends are found, however, these are not all relevant for the research question so only the most relevant are chosen or that show interesting opportunities to consider. The selection of relevant trends is made in collaboration with two other design students from the master SPD who have experience in doing trend analysis to make sure the selection does not miss any interesting opportunities. This selection is based mainly on two things: one is whether it relevant for the research questions and the other is by looking for links between Miscanthus packaging opportunities and market trends. A list of the most important trends is made:

Trend 1: Target group with the largest income is 40-60 year old

One opportunity that emerges from the results for introducing Miscanthus based packaging, is the fact that people from 40 to 60-year-old have the largest income, are currently the largest age group, are more conscious about the environment and, are willing to pay for it. For answering RQ2 (How to position a new type of sustainable packaging made from Miscanthus on an existing market?) this opportunity is interesting because it can provide a target group or a marketing strategy directed to this target group.

Trend 2: Travel branch is the quickest growing sector

The economic trends show that there is an opportunity in the travel branch. The travel branch is currently the quickest growing sector in passengers and revenue. This is an interesting opportunity for the local for local aspect discussed in Section 1.1.3. Besides, this is relevant for RQ2 because it can provide an interesting opportunity for positioning a Miscanthus based packaging on the travel market.

Trend 3: Single-use plastic ban in 2021

From the political trends, only one emerged that showed to be relevant, which is the EU banning single-use plastics in 2021. The banned single-use plastics leave a gap of products that probably need a sustainable replacement. For Miscanthus based packaging this is an opportunity and relevant for RQ2 because some types of packaging will be prohibited, leaving a gap in the market that can be filled by Miscanthus based packaging

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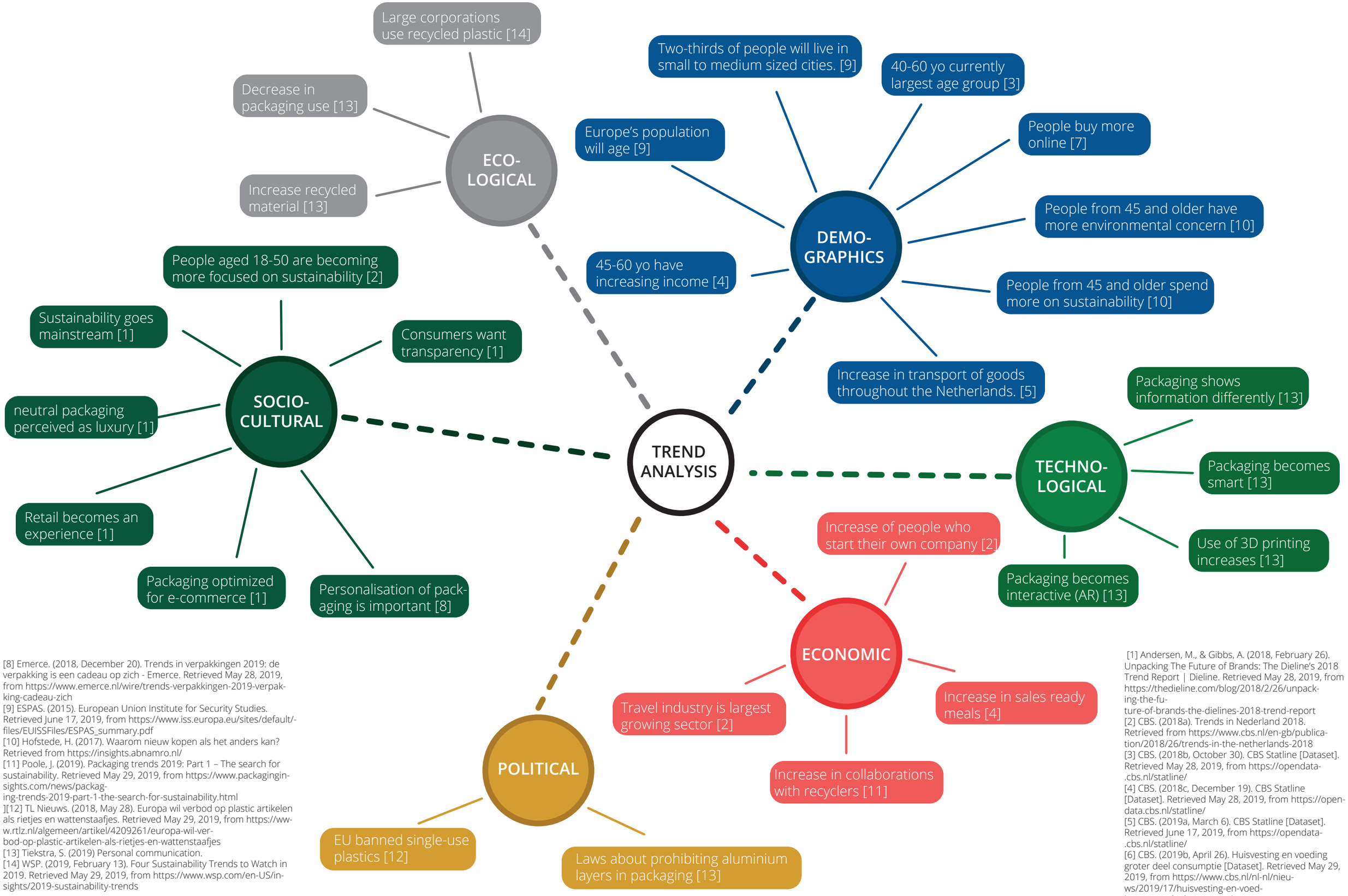
Trend 4: Sustainability going mainstream

In the sociocultural domain, an important trend is sustainability going mainstream. This provides an opportunity for creating sustainable packaging which is presumable also accepted by the consumer. For RQ2 this is an interesting opportunity because Miscanthus packaging is a sustainable alternative to other non-sustainable types of packaging such as single-use plastics. Miscanthus packaging can be positioned as a sustainable type of packaging.

Trend 5: Contradicting trends in the amount of packaging

In the domain ecological trends, there is a contradicting trend compared to the sociocultural, which is the decrease of packaging that is used within the ecological domain and the trend that packaging becomes an experience within the sociocultural domain. In other words, on one hand, more packaging is being used to create the experience and on the other hand, less packaging is being used to be more sustainable. The difference can be seen in the purpose of the packaging. Within the food industry (especially supermarkets), the trend of having less (plastic) packaging can be seen, while in the industry of consumer goods the importance of having an experience while opening the package is important (think of for example unboxing videos appearing on YouTube). These contradicting trends are relevant for RQ2 because it needs to be determined with the purpose of the sustainable packaging whether one or the other will have a bigger impact.



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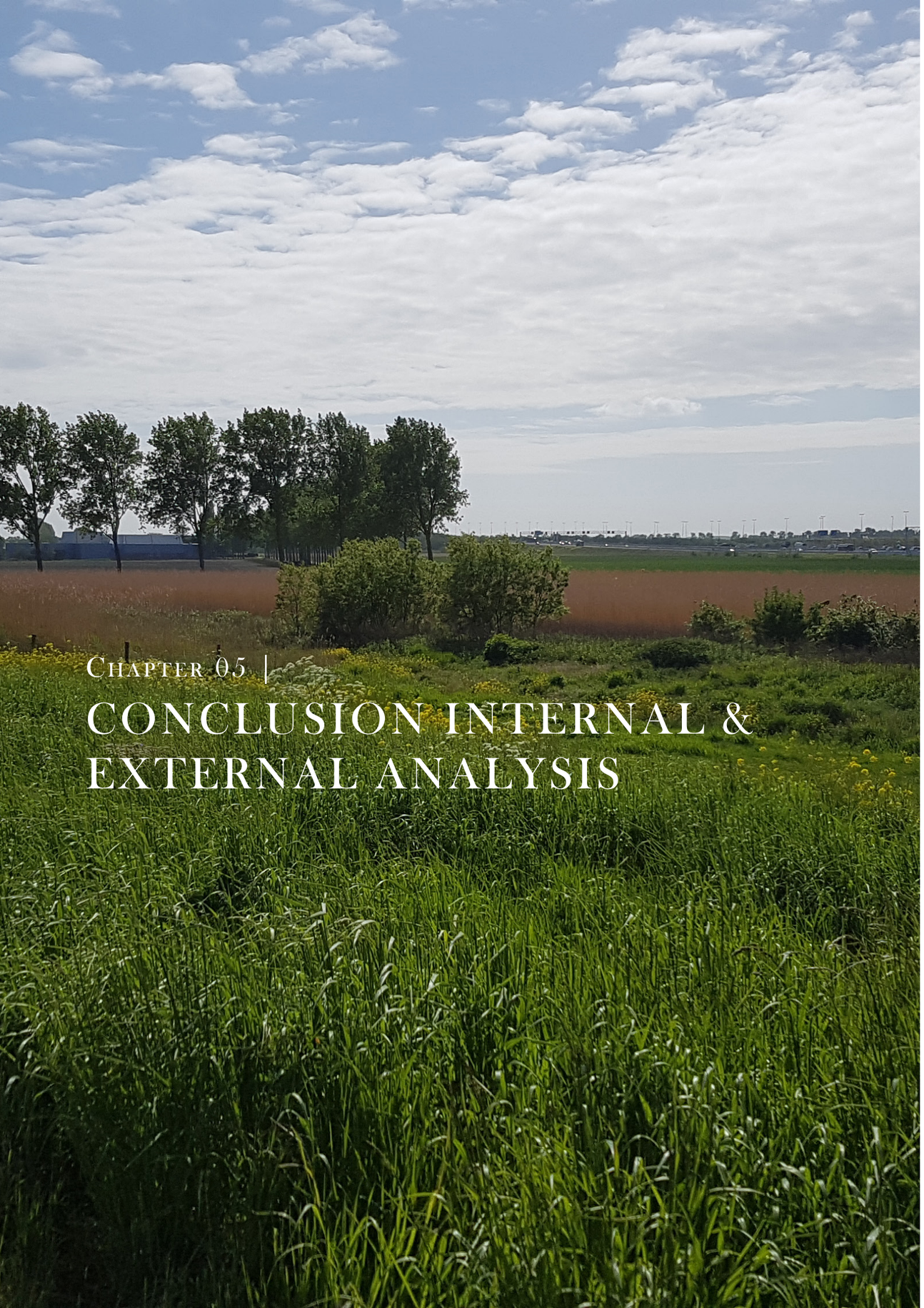


Chapter 05 |

CONCLUSION INTERNAL & EXTERNAL ANALYSIS

This conclusion summarises the findings from the context exploring phase. In this chapter, the domain of Miscanthus and packaging are explored, together with what is happening in the industry and the market by doing an internal and an external analysis.

From the company, analysis became clear that for KCPK, this project is relevant because this thesis will look at the product life cycle of Miscanthus based paper products and the implementation of it in the market. This thesis can contribute to KCPK by researching the possibilities of packaging made from Miscanthus and the possibilities for it being implemented using a circular model.

When looking at Elgra, this thesis will provide them with a clear roadmap and strategy they can use when developing Miscanthus based packaging. Concerning the capabilities of Elgra that are relevant for the Miscanthus, packaging strategy is that all financial resources come at first from private investments or subsidies. This is relevant to notice because it provides input on the financial side of the roadmap. Besides, the cultivation of Miscanthus is done within the company itself and they are planning on moving up the value chain by incorporating the development of Miscanthus based packaging within their own business. By implementing this in the roadmap, strategic decisions can be made for Miscanthus based packaging which fits the future ambitions of Elgra. Furthermore, currently, Elgra is still operating as a start-up since they have limited resources and the company does not make enough profit to provide its employees with full-time salary payment. The advantages of being a start-up are that they do not have the constraints a larger company has. They are still flexible, meaning that if it turns out that Miscanthus based packaging is not viable or feasible, they can pivot the company to a more fruitful direction without it doing too much damage to the company's resources.

After researching the context of Miscanthus, some important insights emerged within the different domains. From the biological domain of Miscanthus, it was proved by literature that Miscanthus as a crop is suitable for paper production and with this, the opportunity emerged for Miscanthus being a potential developed into a CO2 neutral packaging.

When looking at the natural environment and the demographics of Miscanthus, there are many benefits of Miscanthus growing next to Schiphol. It absorbs the dust particles from the aircrafts that are flying over it, it grows on the nitrogen and CO2 emitted from

the greenhouse gasses, it hinders geese from coming near the airport and due to its deep roots, it dampens the sound coming from ascending and descending aircrafts. Because of its benefits for the environment, Miscanthus packaging can be used as a local for local type of packaging, where Miscanthus is cultivated, used and recycled locally.

There is an opportunity to deliver Miscanthus based packaging to Schiphol since when looking at the trends, the travel industry is currently the largest growing sector. With a growing demand for Miscanthus, the current selling price of €0,20, which has a low margin, can increase to give more profit to Elgra.

Also, introducing Miscanthus based packaging in combination with the trend of sustainability going mainstream and the trend of EU banning single-use plastics in 2021 can play into the need for sustainability for companies at Schiphol. They can gain a better positive brand image in a yet already 'environmentally burdened' market of the airport industry. In addition, again the local for local aspect is interesting in this market. Miscanthus grows near Schiphol and Elgra plans on building a Miscanthus packaging facility in the area of Schiphol.

When looking more closely at the Miscanthus packaging material itself, the process of papermaking can be done in different ways, each way has its benefits and disadvantages that need to be considered when designing sustainable Miscanthus packaging. From the previously done research, it became clear the strength of the paper needs to be made higher with additives since the current strength low and the material immediately disintegrates when it comes in contact with water. This can be solved by adding additives or adding recycled paper to the mixture, this needs to be considered in the value chain. The colour of the Miscanthus based packaging material is mainly yellow if no bleaching is done, this turns to grey when recycled paper is added.

The industry forces also describe what materials Miscanthus based packaging could substitute. Hemp and recycled paper are the largest threat to Miscanthus based packaging. Mainly because they are easy to switch to for companies, like changing virgin fibre paper to recycled paper. However, each of these has downsides that Miscanthus can use in its advantage. For example, Hemp is more difficult to harvest and needs specialised equipment for cultivation. Miscanthus is, in this case, easy to cultivate with existing machinery, when Miscanthus paper is used with the right additives it can contain hot beverages and degrade under natural circumstances, furthermore, each year there is a large supply of virgin material that can be used for food containing packaging without needing the heavy cleaning with chemicals.

In the context exploring phase, also other circular business models are explored. The business model of "Resouce recovery" is the most suitable for Miscanthus based packaging because Miscanthus can be recovered and recycled easily with existing equipment. Kartent and other collection programs from for example coffee cups have the advantage of having a closed system where the products are introduced in a market and collected from the same location. Besides, they have a constant stream of used product that can be reused/ recycled. The price of the product should stay attractive as well, people need to be able to choose the sustainable alternative for a similar price as the non-sustainable alternative. Kartent has a lot of collaborations to close the product life cycle and make the business viable. Another important insight is that having collaborations with other paper companies in the sector like paper waste managers can improve the business case to create new products from waste streams.

The conclusions from the context exploring phase will be used as input for the Deep dive and synthesis phase.

Chapter 06 |

MARKET OPPORTUNITIES

6.1 Opportunities (SWOT)

As a conclusion of the context, internal and external analysis and to find design opportunities a SWOT analysis has been done. From the SWOT analysis, three criteria emerged that will be used as a measurement to test whether a certain market is interesting for Miscanthus based packaging. After the categorisation of the data into the four areas, connections will be made between the different segments to find new opportunities for Miscanthus based sustainable packaging. Because of the large amount of data and to get a view from an external perspective, the SWOT-analysis has been done together with two master graduate students from the faculty of Industrial Design Engineering. To analyse all the data, a list of bullet points with key takeaways is formulated based on the findings of Chapter 4 & 5 (Appendix R). Each point is described, written on a post-it and then placed in one of the four quadrants. After all the post-its with bullet points are placed on the canvas, they are clustered to get a better overview and to cluster the similar ones. Figure XX shows a digitalised visual of the final SWOT analysis.

When all the information is mapped on the four areas or quadrants, together with an employee from KCPK, the relationships between the opportunities and strengths are mapped to form market opportunities. The outcome of the SWOT analysis does not provide specific market segments to investigate, but it gives criteria which a certain market segment should consider. Another brainstorm is necessary to choose a specific market segment. In the next paragraph, the market selecting criteria are formulated

Strengths

Strengths Elgra

- Start-up culture
  Flexible
- Own energy production using lignin
- Elgra does own cultivation. Desire for production in own hands

Miscanthus strengths

- Sound dampening
- Lifespan of plant is 25 years so 23 years of profit from it
- Absorbs nitrogent from exhaust fumes
- Collects dust particles
- Hindres Geese

Weaknesses

Company weaknesses

- Elgra still a start up so resources are lacking
- Want to work with brittle material
- Not yet large market, because there is no product

Miscanthus weaknesses

- When recycled in normal paper waste stream, high quality fibre is gone
- Paper products from Miscanthus (hygenic paper), too expensive

Opportunities

Knowledge of KCPK

- KCPK had knowledge that can be used
- Can help keeping the overview between production and materials

Target group

- Generation X spends most money on sustainability and care most about sustainability.

Organisational

- There are existing infrastructures for recycling

CO2 reduction

- Next to highways for natural barrier
- CO2 absorbtion next to certain industries (e.g. concrete) can lead to greener production (local for local)

Regulation

- From 2020, ban on single-use plastics
- KLM is not in Paris agreement

Packaging opportunities

- Exponential growth of e-commerce
- People are more on the go

Product opportunities, not packaging

- Animal food
- There are little to no paper products

Packaging trends

- Neutral packaging perceived as luxury
- Smart packaging increase

Circularity goes mainstream

- Circularity is buzzterm
- People are more concious about sustainability

Threats

Elgra looses oversight

- Elgra looses oversight about what is necessary for production and what is necessary for cultivation
- Elgra wants too much at once

Plant perception (negative)

- Not waterproof, but waterresistant
- Plant is 3,5m high, cannot be planted everywhere

Contradicting trends to sustainable packaging

- Decrease in packaging use
- Large coorporations only interested in recycled plastic
- Importance of personalised packaging

High prices, not enough sales

- Product does not sell, is not profitable
- There are cheaper alternatives to Miscanthus

Not scalable

- Full yield after three years
- When entering consumer market, demand suddenly high and cannot be met due to 3 years for max yield.

Figure 15: SWOT analysis digitalised

6.2 Market opportunities

From the SWOT-analysis and the previous research, it becomes clear that for a circular innovation strategy to be effective in a certain market, several things need to be considered that will be described in this paragraph. The following segmenting criteria are formulated based on the SWOT analysis and the research done in the context exploring phase:

Closed systems have a controlled environment

The inflow and outflow of the packaging material can be controlled by a company in a closed system.

Constant demand

A constant demand makes for a stable market without many fluctuations

The complex industry of paper

Every production step has a different impact on the final product.

When choosing a market segment, these three segmenting criteria will advise on which market segment will be a possibility for Miscanthus based packaging.

6.2.1 Closed systems have a controllable environment

The first criteria that need to be considered is introducing Miscanthus based packaging in a closed system. A closed system means that the Miscanthus based products will be delivered and the aim is to collect it at the same place. An example of such a system already in place is disposable coffee cups in an office environment. The coffee cups are delivered to the office building by company A, the cups are then used by the employees and thrown away in a separate bin provided by company A. When the bin is full, the used coffee cups are then again collected by company A, who will recycle them into new disposable coffee cups. Sometimes, partnerships are established for the recycling part. In this example, the coffee cups stay inside the office building during use and in the ideal case, 100% of the distributed coffee cups are collected again and recycled to new coffee cups.

For Miscanthus, having such a system in place can also be beneficial. Miscanthus fibres are of high quality (see Section 2.1.1), which means they are long and can be recycled often (M. Adriaanse, personal communication, 2019). When the packaging is not introduced in a closed system, i.e. in an open system, the packaging ends up either in the general waste stream resulting in it being burned at waste processing companies or it ends up in the recycled paper waste stream. Although it is not harmful to the recycled paper waste stream, the individual Miscanthus fibre can never be retrieved, meaning it is lost. This is a low-end application of Miscanthus which does not add to the circular economy philosophy (Ellen Macarthur Foundation, 2013). For Miscanthus, introducing it in a closed system can also be adding to the local for local principle. Having a closed system makes it easier to distribute Miscanthus packaging locally and collect and recycle it locally.

6.2.2 Constant demand

The second criteria that need to be considered are preferably introducing Miscanthus in a market with constant demand. It takes three years for Miscanthus to reach maximum yield (see Section 2.1.2), this means that a sudden increase in demand will be problematic in that the current cultivated Miscanthus fields might not provide enough Miscanthus. Although this can be solved by buying Miscanthus in from other farmers, this is not desirable because additional costs and carbon emissions coming from transport and higher market prices will most likely also affect the costs of the product. In addition to this, the Miscanthus products should not be trend sensitive, meaning that the demand should not be highly dependent on the popularity of a certain trend. An example of this is fashion, where clothes are only popular for a short amount of time. Since the Miscanthus crop stays on the land for 25 years (see Section 2.1.2), expanding the business needs to have a certainty that the demand will increase and not suddenly drop. For example airports, the airport industry will not have large fluctuations in demand of packaging since people will always need to fly in the short and medium-term and will receive packaged goods and buy packaged goods on airports.

6.2.3 Complex industry of paper

The last market segmenting criteria is to consider the complexity of the paper and board industry. Papermaking itself is a complex system where every production step has a different impact on the final product. For Miscanthus based packaging it is important to consider these different steps and what influence they have on the final design because they will have an effect on the costs, the environmental impact and the purpose of the packaging.

Besides, when looking at the principle of economies of scale, it is expected that Miscanthus based products will cost more when they are first introduced. Meaning that competing on price with another sustainable packaging might be difficult. There is already a largely established infrastructure of recycling paper and board in the Netherlands, 85% of all paper and board is already being recycled and from all paper and board being produced in the Netherlands 85% is recycled fibre-based (PapierenKarton.nl, n.d.). For Miscanthus packaging, this means that in combination with the economies of scale, it should have a distinct positioning on the right market for example being a local for local packaging in the airport industry. Local for local makes it distinctive compared to other types of packaging and the airport industry is a growing market segment with constant demand.

6.2.4 Conclusion

Considering the three market segmenting criteria, already some interesting markets emerge. By doing a quick brainstorm using the brainwriting technique, five markets emerge that might be interesting to look further into. These five market segments are:

Airports

Airports are an opportunity because the crop has benefits for airports since it collects dust particles from emissions and there is an expected increase in the number of passengers in the coming years. In addition, Schiphol has formulated in its strategy to become the world's most sustainable airport (Schiphol Group, 2019). Packaging made from Miscanthus can aid Schiphol's strategy by providing an alternative to plastic packaging while still offer single-use items.

Aircrafts

Aircrafts are an opportunity because the number of flights is increasing each year and the travel branch is the largest growing market segment in the Netherlands. Also, airlines are not included in the Paris Agreement. By reducing plastic waste in aircrafts, and providing an opportunity of Miscanthus based packaging as a carbon-neutral packaging, flying can become more sustainable.

Festivals

Festivals are an opportunity because there is a lot of plastic waste at festivals and the new EU laws have a large effect on this sector. In addition, there is an increase in Dutch festivals each year (Hoeks, 2019). This makes it an interesting market to further research. Besides, they are searching for alternatives for plastic disposables. Miscanthus based packaging could be an opportunity as a sustainable alternative to single-use plastics. Festivals are a closed system with the potential for local for local production.

Catering

Offices are an opportunity because of the possibilities to work together with professional catering companies. Besides, people are more on the move and trends show that people eat more often while in transit

6.3 Market selection

Based on the earlier defined market opportunity criteria (Section XX) and the initial market brainstorm, a market needs to be selected for this thesis to give direction to the project and to create design artefacts that fit this market. To select a specific market, the method for finding search area's is used. The input for the search areas usually come from a SWOT analysis (van Boeijen, Daalhuizen, van der Schoor, & Zijlstra, 2014), in this case, the SWOT analysis performed in Section 6.1. The search area method aims to find new business opportunities (van Boeijen et al., 2014). This method was chosen to translate the findings of the SWOT analysis to a new business opportunity that can be further explored in the following deep dive. When formulating possible search areas, the opportunities of the SWOT analysis are placed on the x-axis, the strengths and core competencies of the company are put on the y-axis. By making the combination of the strengths and opportunities, a grid emerges where new insights can be formed.

6.3.1 Goal

To get a broader perspective of the project a creative session was organised to formulate interesting search area's (Figure 16). The goal of the session was to gather as many ideas as possible by the participants of the session by combining the qualities of the plant and the market opportunities in a search area grid. This session was held at the faculty of design engineering. The reason for doing the search area method in a creative session and not as an individual exercise is because it is believed that having people looking at the problem from another perspective can give new interesting insights (Buijs & van der Meer, 2013).

Six different posters were made that showed on the horizontal axes the opportunities and on the vertical axes aspects of the product and material qualities. The opportunities are based on the findings of the external analysis (Section 4). The material qualities of the plant and the material are based on the findings of the internal analysis (Section 3). In appendix M, the session plan that was used and practicalities of the session, and the list of the opportunities and plant/ material qualities can be found.

6.3.2 Method

The creative session had eight participants, all part of the faculty of Industrial Design Engineering TU Delft, some were students, others (assistant) professors, resulting in over 150 different ideas. The participants of the session were asked to brainstorm on a poster in pairs and write their ideas on post-its which were stuck at the cross-section of an opportunity and a product/ material quality. After the session, the different ideas were brought home and clustered (Figure 17). Clustering the ideas was done to create a complete overview of the different ideas that emerged from the session. It helps in categorising the different ideas (Buijs & van der Meer, 2013) and measuring them to the previously stated criteria for a business opportunity.

Figure 16: Creative session

Figure 17: Clustering

6.3.3 Results

Clustering all the ideas resulted in nine different cluster topics. The cluster topics are
:

- Branding
- E-commerce opportunity
- Target group opportunity
- How to recycle
- Packaging = experience
- Climate-neutral
- Schiphol opportunity
- Sustainable packaging ideas
- Product opportunities

In each of these clusters were at least two ideas to be called a cluster. When looking at the three market segmentation criteria of introducing Miscanthus based packaging in a closed system with small demand fluctuations and start with the introduction in a small scale (Section 6.2), the most interesting market segment that emerges from the creative session is Schiphol. There are multiple opportunities for branding at Schiphol, it provides an interesting opportunity for carbon-neutral packaging and different types of single-use plastic packaging are used where Miscanthus based packaging can be an alternative for. The following paragraph explains why Schiphol is an interesting market based on the criteria formulated in Section 6.2.

6.3.4 Conclusion

Closed system & Schiphol

Schiphol can act as a closed system. The distribution of packaging is done at a central point and the packaging waste is again collected at Schiphol too via a dedicated collection program for example. In the deep dive analysis, this assumption will be tested. For Miscanthus based packaging, this is beneficial because the material can more easily be retrieved and recycled into new Miscanthus based packaging.

Constant demand & Schiphol

Schiphol is a growing business, that has been growing over the last years (Schiphol group, 2019). For Miscanthus based packaging there must be no large fluctuations in demand because the crop Miscanthus needs three years to reach maximum yields. Figure 18 shows the number of passengers over the last years (CBS, 2019). From this can be seen that there is an increase in passengers over the last years. There is a downfall of passengers between 2008 and 2011, the assumption is that this is probably due to the economic crises. From the graph can be concluded that the market of Schiphol and flying is a relatively stable growing market with a steady increase in the number of passengers. Even the downfall due to the crisis shows there are fewer passengers but that this rapidly increased over the years and reached its old level.

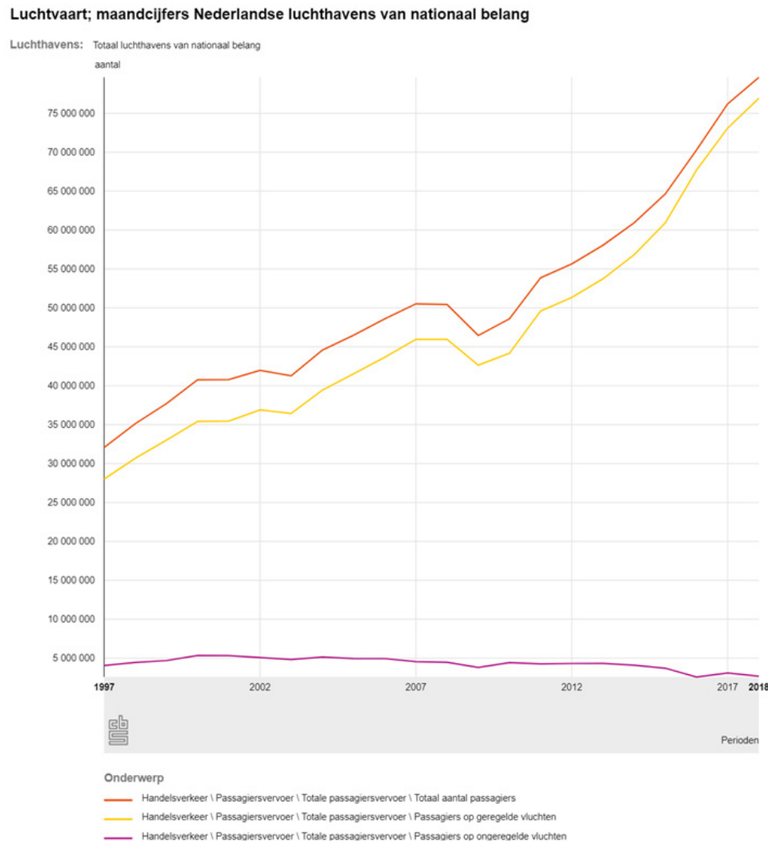


Figure 18: Number of travellers at Schiphol in years (CBS, 2019)

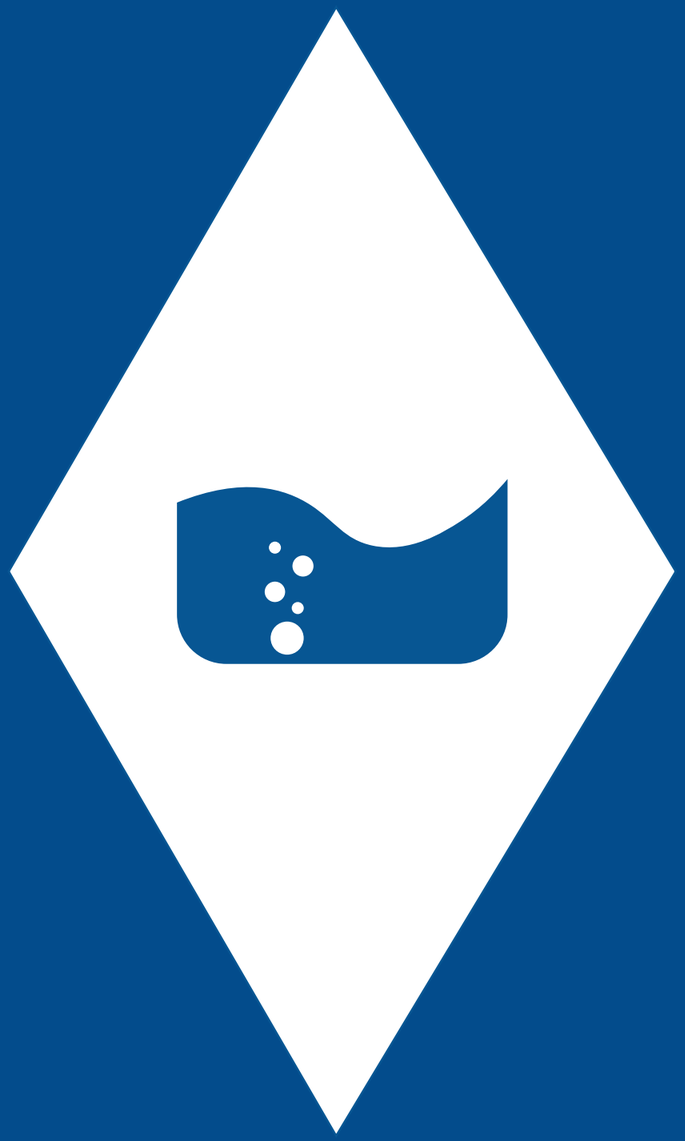
Paper industry & Schiphol

The industry of paper packaging is complex. The benefits of introducing Miscanthus based packaging at Schiphol is that the production process can be tailored to meet the needs of the market specifically. Besides, when choosing to create packaging for Schiphol, there is the opportunity to tell a positive branding story to the consumer because they can learn about the crop Miscanthus at Schiphol and use the Miscanthus based packaging at the same place.

6.4 Conclusion

The assumption that is made here, is that Schiphol is a viable market for Miscanthus based packaging and that has many product opportunities that can be explored. The assumption is tested in the next chapter by conducting a deep dive into the market, exploring the different aspects that come into play when introducing a packaging at Schiphol. To structure the deep dive and give the deep dive a specific goal it must reach a design challenge is formulated. To accompany the design challenge, also criteria have been formulated for the Miscanthus based packaging.

DEEP DIVE & SYNTHESIS



The next phase is the deep dive and synthesis phase. This phase is added to the double diamond approach and focusses on getter a better understanding of the market Schiphol. It provides the reader with a proposed design challenge and a deep dive in the various stakeholders of Schiphol airport. It concludes with a list of criteria that are used for the design of four design artefacts in the last phase.

Chapter 07 |

DESIGN CHALLENGE

As a conclusion of the context exploring phase, the initial research questions will be revisited to formulate a design challenge that will be tackled in the following deep dive and synthesis phase. The design challenge will be an addition to the previously stated research question and will give more context on the original problem. To formulate the design challenge, the structure presented by Roozenburg & Eekels (1998) is used. In this structure, Roozenburg & Eekels (1998) formulate a list of problem characteristics that need to be taken into consideration when defining a problem. This structure is chosen because it shows a coherent list of problem definition characteristics. The complete filled-in structure can be found in appendix N. The design challenge is defined as follow:

Design a circular innovation strategy for Miscanthus based packaging at Schiphol, with a local for local approach, taking into consideration the complex system of papermaking.

Chapter 08 |

DEEP DIVE INTO SCHIPHOL

8.1 Deep dive

As a market, Schiphol airport has been chosen to identify and explore product opportunities such as local for local Miscanthus packaging products because there are mutual benefits both for Schiphol and for Miscanthus packaging. The assumption that is taken here, is that Schiphol is a suitable market for Miscanthus based packaging. The deep dive will test this assumption.

8.1.1 Goal

With doing a deep dive, the goal is to find product opportunities for Miscanthus packaging and identify the needs for a specific packaging, but above all identifying the necessary steps to implement a Miscanthus based packaging which will be used as input for the roadmap. The reason to choose to do a deep dive is that Schiphol is a complicated market segment with a lot of different companies that are involved. Every involved company has different needs and qualities and not all are expected to be suitable for Miscanthus based packaging. Figure 19 shows a visual representation of how each company at Schiphol interacts with each other.

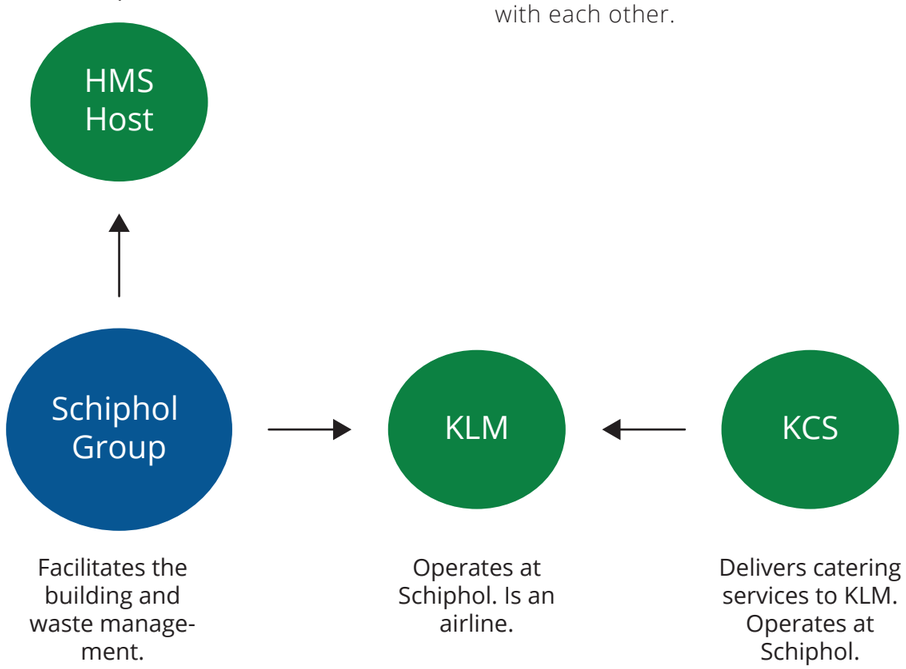


Figure 19: Interaction companies at Schiphol

8.1.2 Method

For the deep dive, semi-structured interviews have been conducted with various companies (Appendix T, U, V, W), all operating at Schiphol and that have an affinity with product packaging. The companies that were interviewed are KLM Catering Services (KCS), responsible for all the catering facilities on board of an aeroplane; KLM, HMS host, and Schiphol group. The reason to only look at these companies is that they are the largest companies operating at the airport that presumably make use of packaging and the assumption is that they are also in need of a sustainable alternative for the current packaging they use. For further research, also my research done for an internship at KLM has been used.

During the interviews, information was gathered about waste management at Schiphol, what the role and function were of the company, additional rules and regulations that might be applied to certain products and some questions about sustainability were asked. The reason to ask for these specific topics is that they will provide the strategy with relevant information about the implementation of a Miscanthus based packaging that fits the needs of the companies operating around Schiphol. For each of the researched companies, a company profile is set up to be able to compare then and to determine which company is the most interesting opportunity for Miscanthus based packaging. The reason for choosing to make a company profile is so that the companies can be compared with each other and estimation can be made about the batch size of Miscanthus based packaging. A company profile answers the 5W & 1H questions and examines if there are any product opportunities:

- Who: Who is the company?
- What: What do they do?
- Where: Where are they situated?
- How: How do they operate in terms of waste management, laws and regulations, people?
- Why: Why are they an opportunity for Miscanthus based packaging?
- When: When do they want to reach their sustainability goals?
- Product opportunities: What specific product opportunities are there and why are they relevant?

8.1.3 Results

By answering the 5W & 1H questions, a complete overview of the company is created that will determine whether it could be an interesting partner for introducing Miscanthus based packaging. In appendix S, the different company profiles can be found. Here, the strategic aspects for Miscanthus based packaging will be discussed per company.

Schiphol Group

From the semi-structured interview with a senior manager from Schiphol Group, it became clear that they do not sell packaged products. They mainly collect waste for the stores and other facilities at the airport and maintain runways and buildings. The only type of packaging they sell to consumers is the famous See/Buy/Fly bag (Figure 20), which is also a recognizable element of their brand image towards consumers. Schiphol Group is a company that can offer a closed-loop system since they collect their waste and distribute the products themselves to consumers. When looking at constant demand, Schiphol Group has no products except for the plastic bag. The plastic bag is given to passengers that buy something at airside before their flight. For Miscanthus based packaging this could be a product opportunity. The plastic bag has a specific brand image that makes the airport Schiphol recognizable for tourists, so changing the appearance might affect the brand appearance of Schiphol. The local for local aspect is also possible with Schiphol Group since they own various airports in the Netherlands, meaning the packaging can be offered there also. Besides, Miscanthus already grows around Schiphol, this can be extended to other airports in the Netherlands. This will be further examined and included in the roadmap. When this market is chosen, the assumption that the consumer will have a different response to the packaging experience should be tested. Another possibility for Miscanthus based packaging for Schiphol Group is for a collaboration when packaging is introduced in the hospitality sector for collection purposes. Schiphol Group can be a strategic partner that collects the Miscanthus based packaging separately so it can be recycled at Elgra and closing the loop.

Figure 20: See buy fly bag

HMS Host

For Miscanthus based packaging, HMS host is an opportunity because of their use of single-use plastic packaging. They offer many different types of packaging at a lot of different locations at the airport but also in the rest of the Netherlands at for example railway stations. However, HMS Host does not buy their packaging materials, this is outsourced to Victoria trading. Besides, at Schiphol, HMS host does not collect their waste, meaning they have little to no influence on where the packaging ends up. They are mainly a linear company that only partake in a small part of the supply chain (only distribution). From this can be concluded that introducing a Miscanthus based packaging in a closed system is difficult when a partnership with only HMS Host is in place because HMS Host has no say in what happens with their packaging, this can be overcome when a strategic partnership is established with both HMS Host and Schiphol Group. Then, on one hand, HMS Host provides the packaging to the customer and Schiphol Group manages the collection of the Miscanthus packaging waste. Besides, HMS host operates on such a large scale, that changing a type of packaging only at Schiphol is not what they would want to do. According to the interview with the managing director of food and beverage, when packaging material is changed for Schiphol, it should also change for the 18 other countries in Europe they are currently operating in. Making it difficult for Miscanthus packaging to scale up slowly and meeting the demand when HMS Host is a launching customer. Also, the local for local aspect is in this case lost. This could be overcome by extrapolating the Miscanthus packaging production across Europe near HMS host locations, this can be used for later in the roadmap and not as a launching customer.

KLM

For KLM Miscanthus based packaging is an opportunity because it is a closed system, the products are used inside the aircraft and the used products are brought back to Schiphol for recycling in European flights. In addition, they are currently actively looking for a packaging alternative for single-use plastics. Miscanthus packaging can be used for catering purposes such as sandwich boxes or coffee cups, replacing the current paper and plastic packaging they have on board. KLM has recently launched a new campaign, called ‘Fly Responsibly’, in this campaign they hope to make customers more aware of how they can be more sustainable and about what KLM is doing to become more sustainable. KLM has set the target that by 2030, they want to reduce residual waste by 50% compared to 2011. They want to achieve this by for example reducing the amount of cardboard used onboard and by recycling the cardboard. Miscanthus based packaging can be an alternative to this and help in achieving the goals of reducing residual waste by being recycled to new Miscanthus based packaging. KLM has a constant demand for packaging because the number of flights is increasing and the assumption is that they will still be offering catering in the short and medium-term that needs to be packaged. During the interview with KLM, it became clear that they are searching for new packaging materials to replace the current plastic packaging. One explicit example is the plastic wrap that is currently used to package the KLM blankets. These blankets are given to people on the aeroplane. To replace this wrapper could be a product opportunity for Miscanthus based packaging.

KLM Catering Services (KCS)

Miscanthus based packaging is an opportunity for KCS because it can replace single-use plastic packaging that is used on board of the aircraft. Besides, costs can be saved for transport because the Miscanthus grows close to the airport, adding to the local for local aspect. Furthermore, KCS is already skilled in separating waste, therefore adding Miscanthus packaging with a separate waste stream is not seen as a problem by the R&D director of KCS. Since KCS offers packaging to aircrafts and collects the packaging again after use, a closed system is also in place here. Also, since KLM has a constant demand, this means KCS has a constant demand because KCS is a subsidiary of KLM. The interview with KCS was held at the KCS office. Together with the interview, also a tour through the facility was given. During this tour, some interesting product opportunities emerged that might be interesting for Miscanthus based packaging. One of these product opportunities is a small cardboard box that is used for pre-made sandwiches. This small cardboard box could be made from Miscanthus paper. Another product opportunity is the business class beauty cases. These are distributed in business class to passengers and contain small refreshment items such as a towel, soap and a toothbrush. These beauty cases are packed in plastic and once opened, they cannot be recycled anymore and must be incinerated. In a lot of occasions, the passenger opens the beauty case, takes one or two items and then leaves the case in the aircraft. Figure 21 shows wasted beauty cases. For Miscanthus packaging this is an opportunity because the current packaging contains multiple materials and is more difficult to recycled compared to a Miscanthus based packaging. The assumption that is made here, is that the Miscanthus beauty case has the same sense of luxury as the current beauty cases, this should be further examined.

Figure 21: Wasted beauty cases

8.1.4 Conclusion

When comparing the four different companies, it becomes clear that there are product opportunities for Miscanthus based packaging at Schiphol. When looking at the three market criteria formulated in Section 6.2, they can also be used to determine which specific market segment is interesting to move into. Each criterion is discussed and compared to a different company.

Closed systems have a controllable environment

The first criterion is the ability of the company to have a closed system. For Schiphol Group in collaboration with HMS Host, and KLM Catering services (and therefore also KLM) this is possible. They manage their waste streams and can decide whether they are willing to add another waste stream of Miscanthus based paper. For HMS Host on its own, this is more difficult because they sell directly to consumers for on the go and it is hard to regulate where the consumers separate their waste. Besides, HMS Host does not manage their waste streams, this means that the system is not closed, and it makes it more difficult to create a separate Miscanthus waste stream. A separate collaboration with Schiphol Group is necessary to collect the Miscanthus based packaging for recycling. Besides, for the collaboration Schiphol Group and HMS Host, the local for local aspect is difficult to realise. When HMS host wants to implement Miscanthus based packaging, they want to do that for the whole EU market. In this case, the local for local element is not possible to realise in the short term. For

the longer term, there are opportunities for Miscanthus based packaging. For KLM and KCS, the local for local aspect is easier to realise because the Miscanthus based packaging is distributed and collected at Schiphol and from there can be recycled to new Miscanthus based packaging.

Constant demand

All three companies have relatively low demand fluctuations, based on the insights gained from the conducted interviews. Although the demand of Miscanthus packaging is a lot larger for HMS Host compared to KLM and KCS since HMS host has a far larger operating area and the Miscanthus packaging is not only implemented in the Netherlands but also 18 other countries at once according to the interviewee. Schiphol Group only sells one product (the See/Buy/fly bag), expanding the Miscanthus packaging to other products is therefore not possible, making the market demand relatively low. From this can be concluded that the most likely partner to collaborate with in terms of demand fluctuations is KLM and KCS since there is the opportunity to slowly increase the product line of Miscanthus based products, it makes it easier for Miscanthus farmers to increase the number of crop fields to meet the required raw Miscanthus demands.

The complex industry of paper

When looking at the industry of paper, the price for HMS Host packaging products needs to be as low as possible. It is difficult to estimate beforehand whether the packaging price can compete with the current pricing of the product packaging. According to the interviewee of HMS host, the price cannot be higher than 10% to 20% of the current price, otherwise, the consumers are not willing to pay for the products and do not choose the sustainable alternative.

When looking at the production of the packaging itself, for KLM, KCS and HMS Host, meeting the material criteria should not have any problems because there are many different possibilities of creating paper packaging. For Schiphol Group, the creating the paper bag made of Miscanthus is also not assumed to pose any issues, however, the brand image should be clear.

Concluding from measuring the four different companies to the formulated market criteria, it becomes clear that the least suitable market is Schiphol Group, they have only one type of product packaging that they sell which needs to follow strict criteria on appearance and look and feel. Also scaling up to other product packaging is not an option for them. Furthermore, HMS Host is also considered to not be suitable for Elgra to introduce their Miscanthus packaging as a launching customer. In a later stage when the Miscanthus packaging products are more mature and the supply of raw Miscanthus has increased, there is an opportunity to introduce the Miscanthus packaging in a larger scale at HMS host retail stations, however, currently the supply of raw Miscanthus is too limited to provide for 19 countries of products at once and the system of HMS host is not closed. Resulting in the Miscanthus packaging getting lost in the general recycled paper waste stream. Besides, providing a local for local strategy for HMS Host also proves to be a challenge because of the international context of HMS Host.

This leaves KLM and KLM Catering Services as most likely partners for a launching customer. The system is closed, meaning the Miscanthus packaging do not get lost in the general waste stream, meaning they can be recycled. Also, there are lots of product opportunities to introduce and expand the product line of Miscanthus based packaging, considering they still are using a lot of different plastic packaging and full print paper packaging material.

Chapter 09 |

DESIGN CRITERIA

In addition to the Design Challenge, also design criteria are formulated. These design criteria will be used to design certain design artefacts in Section 10 and will make sure, the design artefacts are fitting to the design challenge. The reason to choose design criteria to form guidelines for the design artefacts is that the design challenge itself does not give specific directions on what to design. Besides, the design criteria will also allow looking at all the aspects of the product life cycle and give additional input for formulating a product life cycle that is feasible.

Three interviews have been conducted with experts from the field of sustainable packaging to help in formulating design criteria. These experts are from different companies: Bio4Pack, Biofutura and Paperwise. The interviews and the interview guide can be found in appendix O, P & Q respectively.

The design criteria are therefore based on the results of the SWOT analysis (Section 6.1), the design challenge (Section 7), expert interviews and the deep dive (Section 8.1). Each criterion is labelled with a code (e.g. M19), which refers to a certain insight. The insight list can be found in Appendix R. The list of criteria is structured based on Pugh's checklist, provided by Roozenburg & Eekels (1998). This is a checklist which consists of 21 items, discussed here below:

Performance

- 1.The final design solution must be a packaging for another product. [T3, FC1, IPG1, M12]
- 2. The packaging should protect the product inside from damage. [ST]
- 3. The packaging should make the product inside easy to transport. [T10]
- The packaging holds different elements together.
- 4. The packaging should be a primary or secondary packaging. [ST]

Environment

- 5. Target group are people traveling via Schiphol, using KLM. [T2, IHE1, M1, M3

Lifespan

- 6. The Miscanthus based packaging is introduced in a circular business model. [SPC8, FCIS2, IWM5, IWM8, IWK5]
- The packaging must be a local for local initiative.

Production costs

- 7. The price should not be higher than other similar sustainable packaging made from an alternative fibre, it will not compete in price with plastic packaging, therefore the comparison is only with packaging from an alternative fibre. [ST]

Transport

- 8. Transport from the farmland to the production facility and from the production facility to the point of sale (p.o.s.) at the airport should be with the lowest possible emissions and lowest possible costs. [SPC3]

Packaging

- 9. The tertiary packaging of the design solution should be minimized to as little as possible and made from a sustainable material. [SPC7]

Production facilities

- 10. The production process must have clear waste streams that do not harm nature in any way and is optimally efficient for the desired application. [SPC1]
- 11. The Miscanthus packaging will be produced using existing paper production methods.

Size and weight

- 12. The size of the packaging will not exceed the maximum size of the production facility. This depends on the final design solution and the chosen production method.

Form, colour and finishing

- 13. The colour is yellowish, no bleaching or deinking necessary. [M]
- 14. Form follows function, the function of the packaging has priority over the aesthetics of the packaging.

Materials

- 15. Packaging must be from made from Miscanthus, potentially reinforced with other plant-based materials resulting in a sustainable packaging. [T4, M11, M12]

Product life span

- 16.Packaging should be introduced at KLM aircrafts or Schiphol which is a controlled environment with no large fluctuations in demand to be able to provide a constant stream of manufactured products. [M20, M28, T2]

Norms and standards

- 17. When the packaging is used for food, it must meet to the food safety regulations (Section XX). [IFV1]
- 18. The packaging must be recyclable and fit in the industrial recycling facilities of paper recycling streams. [IMA2]
- 19. The packaging must not contain any plastic from a fossil origin. [SPC1]

Ergonomics

- 20.The packaging must be easy to handle by the consumer.

Reliability

- The packaging only breaks when mishandled by the consumer or manufacturer.
- A tamper evidence mechanism will be used to show tampering of the packaging.
- Storage
- The storage facility of the raw Miscanthus and manufactured miscanthus packaging should have no moist and keep the product integrity at a high level.
- There is limited availability for storage space so overproduction should be minimized.

Safety

- 21. Is safe to use by consumers. [SPC1]
- 22. The production facility does not harm the environment in any way. [SPC5]
- 23. When used for food, particles of the packaging will not transfer on the product it contains. [IVF1]

Product policy

- 24. To provide a service, not aimed at one-way consumption. Is effectively recovered and utilized in biological and/ or industrial closed loop cycles. [SPC8]
- There are no criteria regarding the second generations Miscanthus packaging however the product line should be consistent.

Social and political implications

- 25. Packaging needs to communicate a clear purpose with a strong message to explain the focus on sustainability to the consumers and to differentiate from already existing products. [M18, M19, T16, IPG1, IPG9, IPG10, IWM11, IWK5]
- 26. The packaging should be an alternative to regular plastic packaging.

Installation and commissioning

- 27. Since the packaging will be introduced in a closed system, the packaging should be used and collected at specially provided areas.
- 28. The consumer must clearly know where to dispose the packaging after use.
- 29. The commissioner must have an influence on the buy-in of packaging materials to be able to decide to choose Miscanthus packaging.

Reuse and waste processing

- 30. When the packaging does not stay in the closed system, so discarded outside the system, the packaging should be recyclable via the conventional means, when it is not disposed in the designated area.
- 31. The packaging must be a mono material or easy to separate with recyclable additives. [IPG4]

Whishes

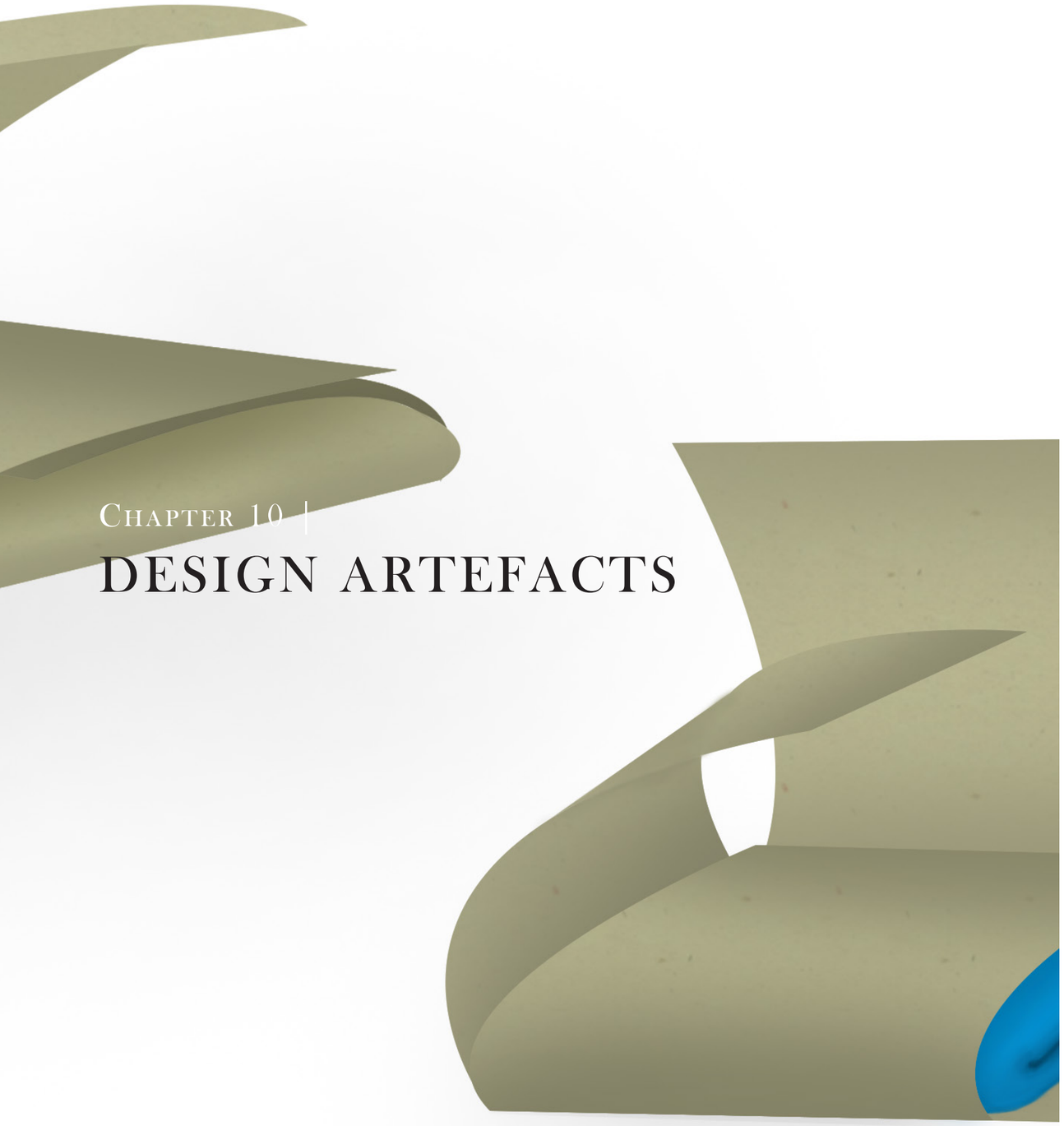
In addition to the criteria, also wishes are formulated. These wishes are additional to the criteria and are nice to have and not a must. The whishes are based on the same research done for the criteria, explained

above.

1. The packaging should have preferably multiple functionalities or is modular to move from single use to multiple use or be suitable for cascading possibilities. [IPG6, WM6]
2. To create certain barrier qualities, coatings or additives are necessary. When this is the case, they should be either recyclable, from a sustainable alternative or from a renewable source.
3. The packaging should be preferably compostable. This does not have to be communicated but only for backup. For recycling the packaging does not have to be compostable. When the packaging becomes industrially compostable, it must meet the EU criteria of EN 13432. [IPG2]:
4. The packaging is sourced, manufactured, transported, and recycled using renewable energy. [SPC2]

CIRCULAR INNOVATION STRATEGY BUILDING

The third diamond is the circular innovation strategy building phase. This phase presents four different design artefacts to illustrate four different strategic routes the strategy can take. Also, an short term implementation, an LCA and a value proposition. This chapter ends with a conclusion on what artefact is for Elgra the best way to move to.



Chapter 10 |

DESIGN ARTEFACTS

From the deep dive, it became clear that KLM as a target market is an opportunity for a first Miscanthus based packaging to introduce. From the deep dive, the conclusion stated that the focus should lie on KLM and KLM Catering services as a potential launching customer. KLM handles 33 million passengers each year (KLM, 2019), this number is used to determine the batch size. When exploring the context of KLM catering services, different product opportunities arise. Since the design challenge of this thesis is to design a circular innovation strategy for Miscanthus based packaging, the goal is to formulate a strategy and not to technically design the product. Therefore, this thesis will only present four different design artefacts that will explore the possibilities of taking different design routes. A design artefact is a way to illustrate the strategic decisions that need to be taken (Simonse, Iwanicka, & Whelton, 2018). The reason for only showing a design artefact and not to fully design a product is because they will show the necessary information on the consequences of choosing a certain design route. Besides, there are many different variations of product directions that could be designed but the result still depends on what Elgra can produce and what KLM catering needs. This should be decided on in a later development stage after this thesis is finished by those two parties.

Figure 22 shows a graphical representation of the design routes that can be taken to come to a certain type of design artefact. There are alternative routes that can be taken for the design artefact, for example, more experimental ways of pulping such as bio pulping with the use of fungi, however, for the illustration of the most feasible possible design directions the most common elements are chosen. These elements do however come back in the roadmap as a future production process of Miscanthus based packaging because they show a great potential of becoming common in the paper industry and suitable for local for local production.

The first decision that should be taken is whether the product must contain food or not. Deciding the purpose of the packaging can have a great influence on the later stages of product development in this case, such as the necessity to add a coating or not. Deciding that the final product should be food-related, means the material it is made of should be suitable for containing food. Additional rules and regulations apply, for example, the food regulations discussed in Section 2.1.6, and additional steps are added in the production process of adding

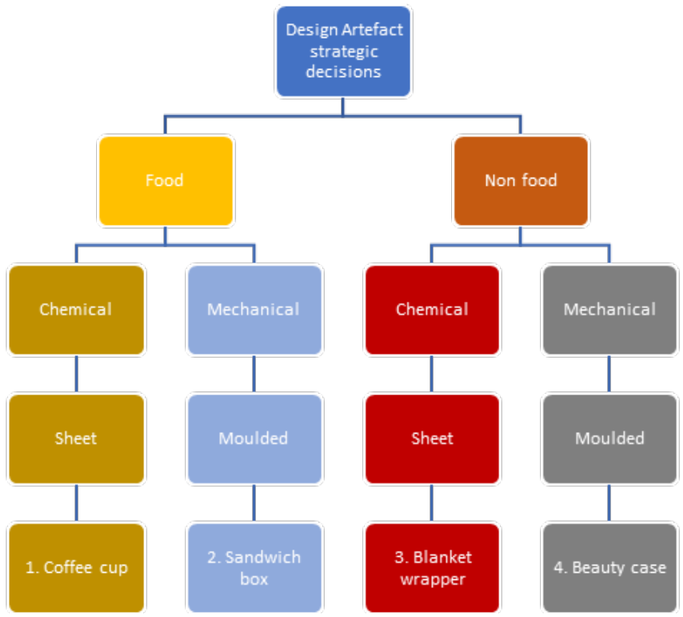


Figure 22: Design routes towards the four design artefacts

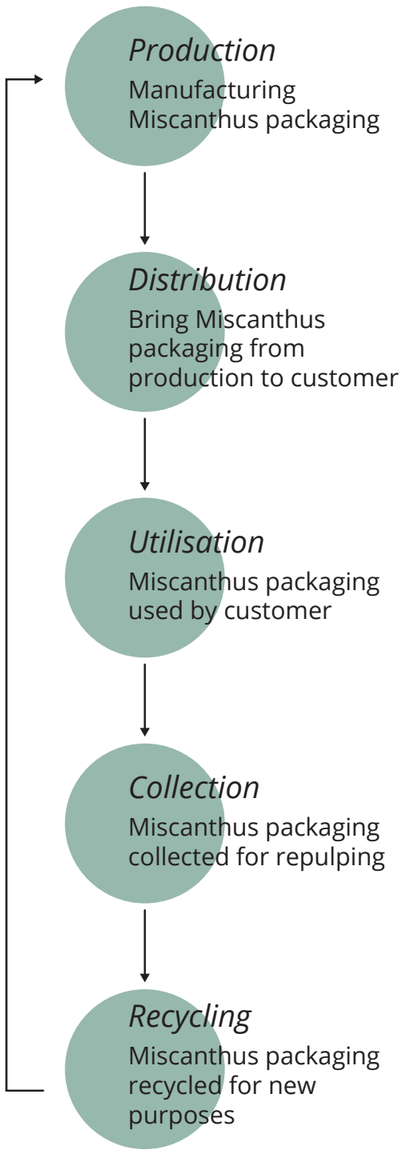
additives and coating to make the material food proof. For Miscanthus packaging to be able to contain food is should be grease resistant, water-resistant and not transferring any of the material into the food. The specific steps per design artefact are further discussed in Section 10.1 about the cup and Section 10.2 about the sandwich box. For non-food packaging, being water-resistant or grease-resistant is not necessary unless the final purpose of the packaging requires it (e.g. packaging for e-commerce might need to be water-resistant). It does not need to have additional EU approved certifications to be food safe. When the design artefacts are used for actual product design, the purpose of the packaging should be determined early on because it will have an impact on the production process (such as adding a coating for example).

The second layer of strategic decisions that need to be made is whether the paper is manufactured using chemical pulping or mechanical pulping. This does mainly depend on the quality of the paper that is required for the end product, this is further discussed in Section 2.2 about the paper manufacturing process. The third layer poses the question of whether the Miscanthus packaging should be made using 3D moulding or sheet rolling to manufacture it. The choice for this depends mainly on the investments for machinery that needs to be made and the purpose of the packaging. In Section 2.2 about the paper manufacturing process, this is further discussed.

The last layer shows the design artefacts. These artefacts are chosen because there were clear product opportunities mentioned during the interview with KLM and KCS and are designed in the simplest way possible since they only illustrate the strategic decisions that need to be made that lie behind such a product. The products are 3D modelled using Solidworks and product renders are made using Photoview 360. The renders are edited afterwards to show a more realistic view of the use of such a product. The appearance used for the renderings is created using the settings of Solidworks and the technical specifications of cardboard are used to determine the weight of the design artefacts. The density of cardboard is assumed to be the most reliable to represent the density of Miscanthus based paper. Each of the artefacts will be discussed based on the product life cycle, the costs will be calculated for the appropriate batch size and an LCA value will be given. The costs and the LCA value will be compared to each other at the end of this chapter. Besides, an implementation timeline will be discussed for each of the artefacts. These results will be used as input for the value proposition and the roadmap by looking at the necessary steps to implement a certain design artefact.

10.1 Design Artefact 1: Coffee Cup

The first design artefact is the coffee cup (200ml) (Figure XX) and is used on board of a plane to have hot and cold drinks. The cup weights 4.1 gram according to Solidworks, assumption is that is it is 100% paper pulp. The cup should be water resistant, this can be achieved by adding a coating. When the waste cups stay seperated from the other types of waste, they can be recycled for new food packaging.



Chemically pulped (abroad, e.g. Germany), sheet rolled (e.g. at Schutpapier (NL)). Assembled (e.g. at Schutpapier). Coated using a layer of e.g. PE for water resistant. When chemically pulped, other elements of the crop can be extracted. For example the lignin, which can be used as biofuel.

Distribution is done by a local distribution company. The products are packaged in batches, sealed in a larger container and transported by truck. The transportation is from the production facility to the customer and from the customer to the repulping facility.

The coffee cup is used on board of a KLM airplane on EU and ICA flights. Estimated passengers use on average 2 cups of liquid. Results in 66 million cups each year, with a margin of 10%, is ~73 million cups necessary each year. To produce this amount of cups 419,02 tonne of raw Miscanthus is necessary assuming the efficiency of chemical pulping Miscanthus is 60%

Collection of the Miscanthus cups should be done inside the aircraft. Such a system is already in place currently. In addition, the incoming used coffee cups should stay seperated at KCS and brought to the recycling facility. All ICA waste is incinerated, estimated is that 50% of the cups are retrieved and recycled (from EU flights, and brought back to NL).

To recycle the cup, the coating should be seperated from the rest of the material. When both are seperated at a waste company, the Miscanthus pulp is brought back to the production facility to be manufactured to new products.

For the roadmap, an alternative for the PE coating needs to be determined so the coffee cup is more sustainable. This alternative can be a different coating, but it is also possible to add additives to the Miscanthus pulp and reach the same result, the advantage of the additive is that the Miscanthus paper becomes a mono material.

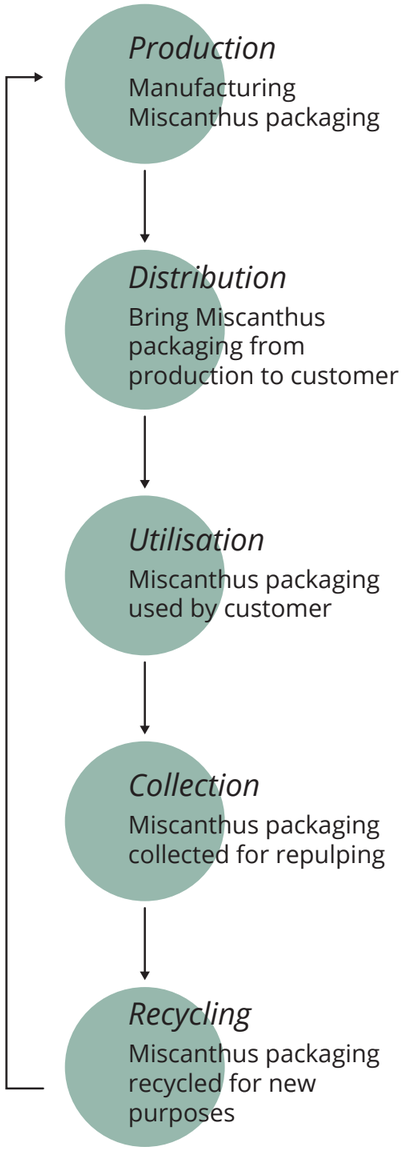
Costs

~€0,040* p.p.

* Estimated on the price of normal kraft coffee cups. This price is a production price.

10.2 Design Artefact 2: Sandwich Box

The second design artefact is the sandwich box (Figure 23) and is used on board of a plane to serve premade sandwiches in. The box has a lid and is laminated and has a food proof certification. In addition, it is grease resistant. The sandwich box weights 34.36 grams including lid. When the waste sandwich boxes stay seperated from the other types of waste, they can be recycled for new food packaging. The box is made of 50% Miscanthus, 50% recycled paper. This increases the strength.



The sandwich box is made by mechanically pulping (e.g. at Huhtamaki) and made using 3D moulding (e.g. at Huhtamaki). After that, the box is filled with the sandwiches (e.g. at a catering company). The sandwich box needs to be laminated to be grease resistant and to gain additional strength.

Distribution is done the same as the design artefact 1. It is distibuted by a local distributer. Packaged in larger volumes and transported by trucks. When the sandwich box is filled with sandwiches, it is transported by a cooled truck.

The sandwich box is used inside the aircraft. Passengers receive it with their meals on board, at ICA and EU flights. KLM serves 24 million meals per year, estimated is that passengers receive 1 box. Results in 24 million sandwich boxes per year, with a margin of 10%, results in ~27 million sandwich boxes necessary each year. Meaning around 930 tonnes of Miscanthus is necessary.

The sandwich boxes are collect on board, preferably in a seperate container. At KCS, the boxes are compressed to require less space for transport. All ICA waste is incinerated, estimated is that 50% of the cups are retrieved and recycled from EU flights, and brought back to NL.

Recyling of this artefact is similar to recyling of the coffee cup because the coating/laminate should be removed for repulping. This is done at a waste managing company. The left over Miscanthus pulp is brought back to the production facility to be manufactured to new products.

Similar to coffee cup, in the roadmap should be included to look for a more sustainable alternative for a PE laminate. For collection of the sandwich box, currently, not all waste is separated on board. This means that when a new type of waste (Miscanthus packaging) is added, it should be separated on board or separated afterwards at KCS. This is however, not favourable because it cannot be used for food packaging anymore due to contamination of e.g. mineral oils.

Figure 23: Sandwich box

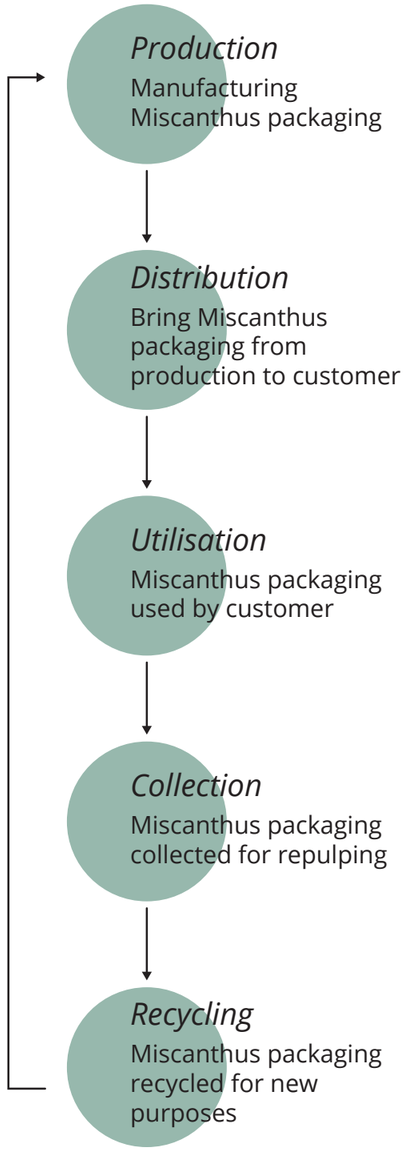
Costs

~€0,049* p.p.

* Cost calculation table can be found in Appendix X, together with an explanation & validation.

10.3 Design Artefact 3: Blanket Wrapper

The third design artefact is the blanket wrapper (Figure 24) and is used to pack the KLM blanket to protect it from getting dirty. The wrapper needs additional strength to not burst during transport. The wrapper does not need any additional coatings or laminates. The blanket wrapper weights 68.64 grams.



The wrapper is made using chemical pulping (done abroad) and made using sheet rolling (e.g. at Schutpapier (NL)). After that, the wrapper is wrapped around the blankets (e.g. at KCS). The wrapper needs additives to gain extra strength, these are added during pulping.

The distribution is done similar to the other artefacts, by a local distributor. The wrappers are stacket and bound together at the paper producer (e.g. Schutpapier), then transported by truck to KCS.

KLM handles 33 million passengers each year, estimated that on half of the flights, people receive a blanket. Results in 16.5 million blanket wrappers each year, with a margin of 10%, results in ~18 million blanket wrappers necessary each year. This means 1735 tonnes raw Miscanthus is necessary, assuming the efficiency of chemical pulping Miscanthus is 60%.

Th blanket wrappers need to be collected on board of the airplane, preferably separate from the other paper materials. When it is not seperated from other paper, it can be separated afterwards at KCS.

The blanket wrappers are collected and send to waste manager. It can simply be repulped and send to the production facility (at e.g. Schutpapier) and manufactured to new products.

The blanket wrappers do not have any coatings that hinder the recycling process. It is a simple product that can easily be recycled. For the roadmap it is important to notice that chemically pulping is not possible in the Netherlands and should be done abroad. Also in the future, because of the relatively small scale it is not possible to have a chemical pulping plant locally.

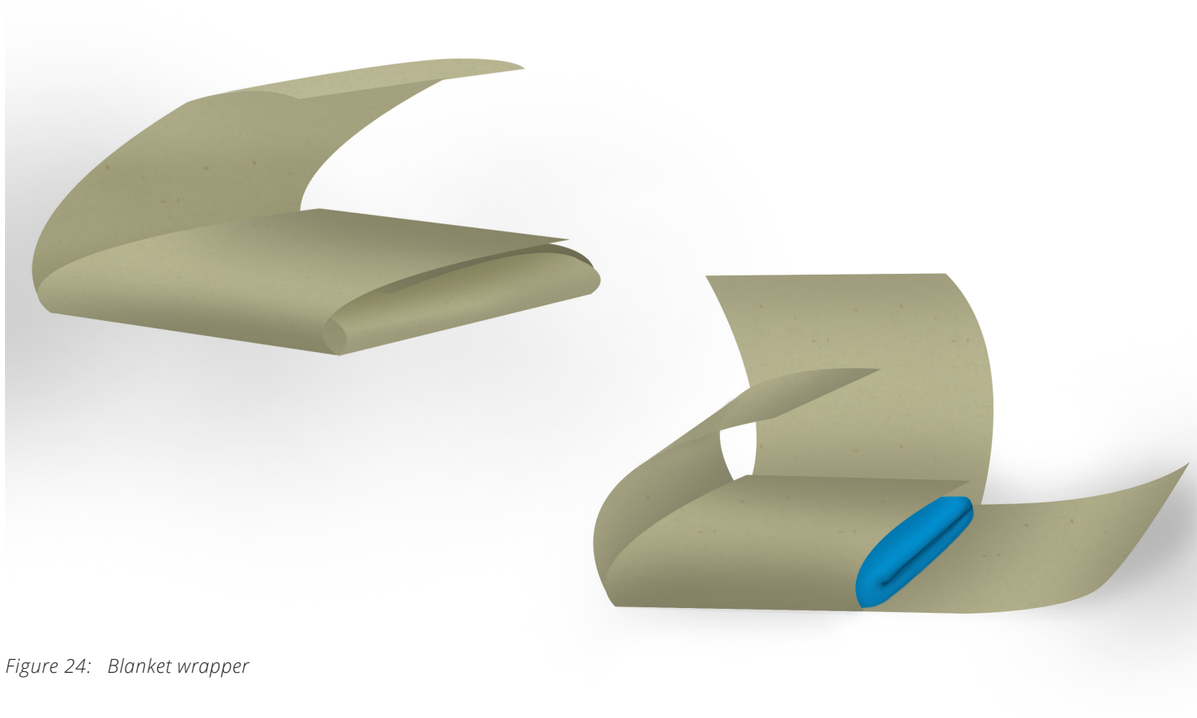


Figure 24: Blanket wrapper

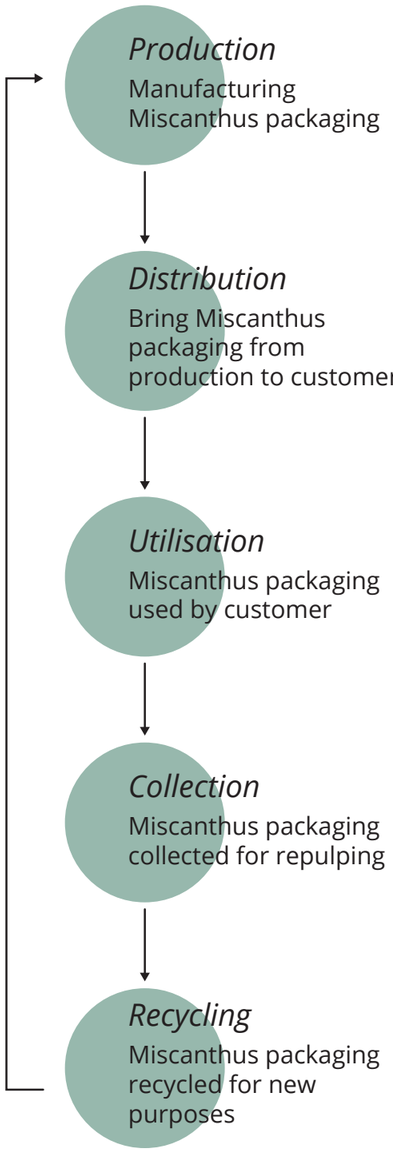
Costs

~€0,50* p.p.

* Based on the production price calculated for Elgra for chemically pulped paper (250g). This price is much higher compared to the other artefacts. This is because this price, is the buy-in price for Miscanthus paper, produced by other companies, the other prices are production prices without profit margin.

10.4 Design Artefact 4: Beauty Case

The last design artefact is the beauty case (Figure 25) and is used to fill with refreshment products to business class. The beauty case needs additional strength to not burst during transport. The beauty case does not need any additional coatings or laminates. The beauty case weights 113 grams. The beauty case is made of 50% Miscanthus and 50% recycled paper, this is done to increase the strength (Section 2.1.4).



The beauty case is made by mechanically pulping (e.g. at Huhtamaki) and made using 3D moulding (e.g. also at Huhtamaki). The beauty case needs additives to gain the additional strength. After the production process it is filled with the necessary refreshment products.

Distibution is done by a local distributor, they collect the MIscanthus and bring it to for example Huhtamaki. There it is manufactured and packed. The products are transported using by truck. The beauty cases are filled at KCS.

KLM handles 33 million passengers each year, estimated 10% fly's business class and receives a beauty case. Results in 3.3 million beauty cases each year, with a margin of 10%, results in ~3.7 million beauty cases necessary each year. The beauty cases are used at ICA and EU flights. 209,5 tonnes of Miscanthus is necessary for production. Assuming a production efficiency of 100%.

The beauty cases can be brought home by the passenger, there it can be thrown away at the regular waste paper stream. When it is left in the aircraft, the beauty case can be collected seperatly for recycling.

The beauty cases can be easily recycled, when additional ribbons or labels are used, they need to be removed and the plain product can be recycled via the production facility.

For the roadmap, it is important to notice that not all beauty cases will be recycled in a separate waste stream and end up at Elgra again. Only the beauty cases that are left inside the aircraft will be recycled. It is not clear how much that will be since it is flight depended.

Figure 25: Beauty case

Costs

~€0,045* p.p.

* Price calculation can be found in Appendix XX, together with an explanation & validation.

10.5 Conclusion

There are 70 hectares of Miscanthus in the Haarlemmermeer. The yield is 20 tonnes per hectare per year. Meaning this is 1400 tonnes of Miscanthus harvested each year. Calculating the amount of tonne available, divided by the weight of the product it shows that for the blanket wrapper there is a shortage of Miscanthus. Besides, for the blanket wrapper, only 60% efficiency is reached when chemically pulping. This results in only 840 tonnes of the total yield of 1400 tonne Miscanthus leftover in paper pulp.

Although there is a shortage at this moment for artefact three, the blanket wrapper, expected is that the amount of Miscanthus fields in the Haarlemmermeer will increase the coming five years. To have enough paper pulp to reach the 37 million artefact three, 3600 tonnes of Miscanthus is necessary, meaning there must be 180 hectares of Miscanthus available. This means significant growth is necessary if the current available Miscanthus field or the shortage needs to be bought at other retailers.

The distribution and the collection are for all artefacts the same. Meaning that there should be a designated collection method provided by KCS in place. The coffee cups can be separated using existing collection means on board of the aircraft and for the other three artefacts, the separation of Miscanthus products should either be on board of the aeroplane or afterwards at KCS.

10.6 Design Criteria

To evaluate the four artefacts to the previously stated design criteria (Section 9), Harris profile is used. A Harris profile is a way to quantify whether a certain design concept (in this case the artefacts) meet the stated criteria by giving it a value from -2 to +2 (van Boeijen et al., 2014). The reason to choose to do a Harris profile is to get an indication if the designed artefacts are meeting the requirements and to see which artefact meets in the best way possible the stated requirements. It is a way to compare the different artefacts based on the criteria. For the Harris profile, some of the criteria have been left out because they are not relevant for the comparison between artefacts. The criteria that have been left out are the ones related to storage and reliability. Storage is left out because it will be the same for all artefacts and it is not relevant to measure on because it does not change the artefacts design route. Reliability criteria have been left out because the purpose of the artefacts is to illustrate the strategic decisions that need to be taken and the reliability needs to be tested and evaluated during product development. The artefacts cannot be measured on reliability since their purpose showcase certain directions and not to be developed. Figure 26 shows the Harris profile for the four different artefacts. Interesting to see is the difference in score between the packaging that contains food and the packaging that does not contain food. The non-food artefacts have a higher score mainly due to the ease of recycling. To create a food proof packaging, currently, most of the time a coating is added which has an impact on the recyclability of the paper. Another interesting aspect that can be concluded from the Harris profile is the difference between the moulded artefacts (2 and 4) and the rolled sheet artefacts (1 and 3). From the Harris profile, it becomes clear that the sheet rolled artefacts protect the product inside less than the moulded products. This can be explained by the fact that the material is thinner and does not hold its shape well.

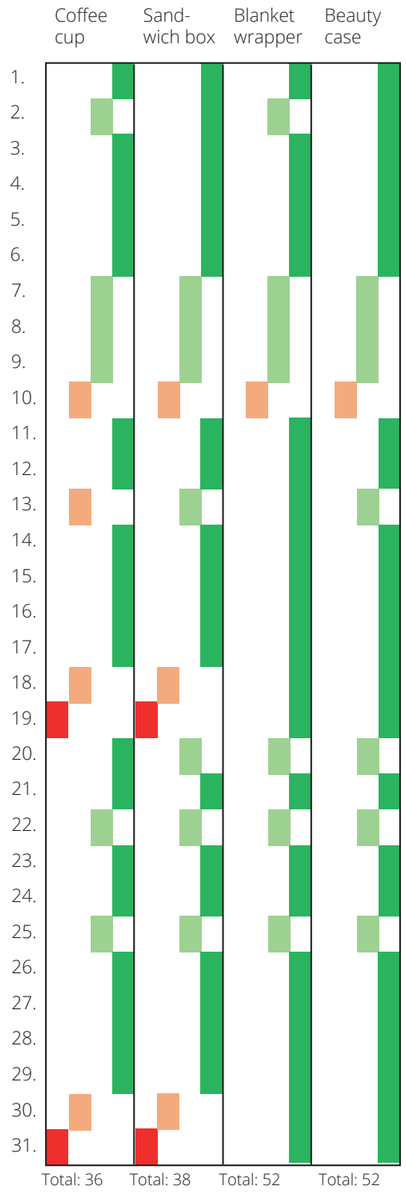


Figure 26: Harris profile, the numbers related to the criteria can be found in Section XX.

10.7 LCA

To calculate the environmental impact per artefact, a fast track LCA is done. The LCA method described by J. Vogtländer (2014) is used to create a fast track LCA. This type of LCA is specifically used by students to make a quick comparison between the different scenario's and products. The difference between a fast track LCA and a regular LCA is that a fast track LCA makes use of excel databases to determine the ecological burden (Vogtländer, 2014). For this thesis, knowing which production method and life cycle have the lowest environmental impact is important because it will help in making strategic decisions that have the lowest possible impact. The book "A practical guide for students, designers and business managers, LCA" (Vogtländer, 2014) is used because it provides an easy step by step approach in creating a reliable fast track LCA. To determine the LCA data, a database is used, recommended by the book. The database that is used is the IDEMAT2018+EI_V3-4, provided by the TU Delft, containing environmental impact values of a lot of different production processes. This database contains the data from the Ecoinvent and the IDEMAT data. The fast track LCA uses a fixed step by step approach, which is also followed to determine the environmental burden of a Miscanthus based packaging, results of the LCA can be seen in Figure 27.

Figure 27: Results LCA in eco-costs

10.7.1 The system

For the system, the chosen Functional Unit is serving per passenger. This is chosen to be able to compare the different LCA's per artefact. The packaging will be single use, meaning its lifetime is several days from the moment the product it needs to contain, until the product is used. This is an estimation. The utilisation of the product will not be taken into consideration because the packaging will be used inside an aircraft. The emissions coming from an aircraft are expected to be high and possibly give an unrealistic image of the environmental burden of the packaging itself. Figure 28 shows the product life cycle, which is the same for each artefact. So, on one hand the mechanical pulping and using that to create a moulded product and on the other hand chemical pulping and making paper sheets from the material. Utilisation is greyed out and is outside of the system boundary.

10.7.2 The scope and goal of analysis

The goal of the analysis is to compare the impact of the different artefacts. At Section 11.3.1, the LCA results of this analysis will be compared to moving the mechanical pulping facility to the Netherlands (locally). The assumption is that mechanical pulping and 3D moulding will have the lowest environmental burden compared to chemical pulping and sheet rolling. All solutions are cradle to cradle, having a circular product life cycle. Recycling is included in the analysis by applying a factor over the different parts of the life cycle.

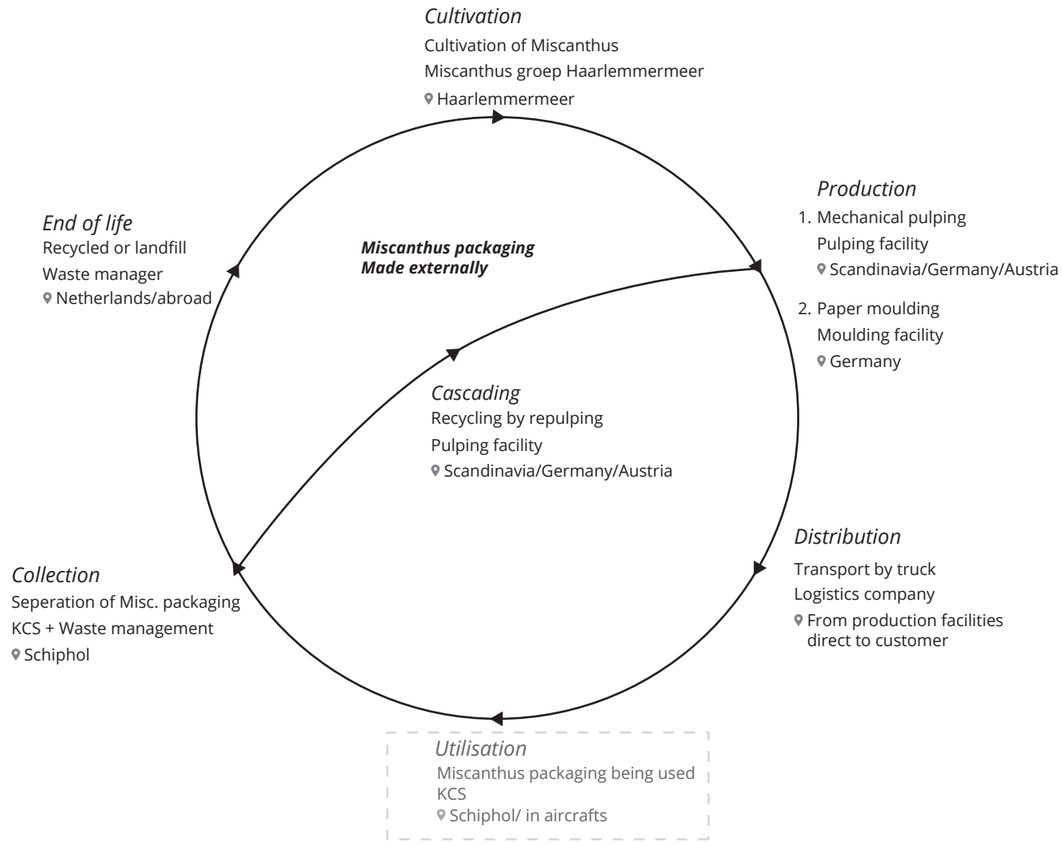


Figure 28: LCA system

10.7.3 Quantify materials

For comparison, the weight of the artefact is 0.1 kg of Miscanthus, the same for all artefacts. With mechanical pulping, this results in 20.000.000 products each year coming from the maximum yield of Miscanthus each year. Which are 2000 tonnes. To reach 20.000.000 products with chemical pulping, more Miscanthus is needed because chemical pulping has an efficiency of 65%. Therefore, to make 20.000.000 products of 0.1kg with chemical pulping, 2700 tonnes of Miscanthus is needed each year. For comparison, the number of manufactured products is also kept the same for all artefacts.

10.7.4 LCA

The fast track LCA is made up of five different stages. Each stage represents a part of the supply chain. For each stage has been determined what the steps are and the eco-costs have been determined. The eco-costs are then multiplied by the quantity of a single step which results in the total impact. The formula used to calculate the total eco-costs per product is:

Eco-costs per artefact = (X*(Eco-$costs_{total}$)+((Y*(Eco-$costs_{total}$ +Eco-$costs_{pulping}$ + Eco-$costs_{production}$ + Eco-$costs_{transport\ pulping\ to\ production.}$ + Eco-$costs_{transport\ production\ to\ customer}$ + Eco-$costs_{transport\ customer\ to\ pulping}$ + Eco-$costs_{transport}$))/2))

X and Y are the factors for recycling rate, so for artefact 1, the coffee cup and artefact 2 the sandwich box, the coating makes that only 40% can be recycled (H. Holwerda, Personal communication, 2019). For arte-fact 3 and 4, the recycling factor is 95% recycled (H. Holwerda, Personal communication, 2019). The formu-la is divided by 2 because the packaging will be recycled in this case twice. Looking at the fuctional unit of servings per passengers, means that one packaging can service two different people because it is recycled. In real life, the products will be recycled much more often.
For this calculation, the assumption is made that the pulping facility is situated in Austria, the moulding fa-cility is situated in Germany and the product is used at Schiphol and repulped at a waste manager in Rijsen-hout. These countries are chosen based on availability of production facilities and might change in a real-life situation.

10.7.5 Results and conclusion

When looking at the results, the difference between the cup and the blanket wrapper is small, the same goes for the sandwich box and the beauty case. When looking at the percentages of the type of impact on the total impact, around 80% of the impact comes from production for all four artefacts. From this can be concluded that the production of artefact 1, the coffee cup and the production of artefact 3, the blanket wrapper make that the environmental impact is higher. Meaning that chemically pulping has a higher environmental impact than mechanical pulping. Due to the limitations of the LCA database, adding a coating to the sandwich box was not included, however, it is included at the coffee cup. Meaning that the impact of the sandwich box is higher than the one stated in Figure 27. However, then looking at the difference of coating to the coffee cup and the blanket wrapper, who have the same production process, the coating does not have a large impact.

10.7.6 Discussion

For the LCA several assumptions are made for using the fast track LCA method that needs to be considered when interpreting the results. The data tables of IDEMAT and Ecoinvent have its limitations concerning production processes. A production process could not be found in the data table which is applying a coating on a moulded fibre product. The assumption that is made, is that the Eco-cost value for artefact 2, the sandwich box, will turn up higher when an extra production step is added because the production method is ~80% of the total eco-cost value. This is considered when discussing the results. The second limitation of the IDEMAT and Ecoinvent table is that it is not clear what the boundaries are of chemical pulping paper. In European pulping factories, often extracted lignin during the pulping process is used for combustion as a power supply for the factory processes (Hooimeijer, A, personal communication, 2019). This results in a lower environmental impact than using fossil fuel, it is however unclear whether this is calculated when determining the eco-costs for chemical pulping in the database, the assumption is made that the chemical pulping method is done with using lignin as a power source for the factory. The last limitation of the fast track LCA is recycling. There are many discussions on how recycling should be included in a fast track LCA (Vogtländer, 2014), in this LCA, the assumption is made that a Miscanthus packaging would only be recycled twice, while the possibility is that a single Miscanthus fibre can be recycled many more times (Adriaanse, M, personal communication, 2019).

10.8 Value proposition

To measure the chosen market segment and to see whether the design artefacts are relevant for KLM and KLM catering services, a value proposition canvas is created (Osterwalder, Pigneur, Bernarda, Smith, & Papadakos, 2014). The value proposition canvas looks at the customer profile, identifying the jobs, pains and gains on the right side of the canvas. This is validated using the right side of the canvas which displays the value proposition. The value proposition consists of gain creators, pain relievers and products and services. Figure XX shows the filled-in value proposition canvas.

From the canvas can be concluded that the Miscanthus based packaging provide value on the whole product life cycle for KLM and KLM catering services. The implementation plan in Section 11.1 is still focussing on producing the products abroad because as an initial product, this is best feasible. For the longer term, the local for local aspect can be further extrapolated by producing the product closer by.

Products and services

- Miscanthus based disposables e.g. the design artefacts

Gain creators

- Reducing transport costs and emissions when local to local
- KLM is willing to pay more for sustainable alternative packaging because of the fly responsibly campaign
- Miscanthus products are recycled to new products, multiple times
- Miscanthus packaging has a low environmental impact
- Miscanthus packaging has a better story that fits KLM and KCS than plastic packaging
- Helps KCS in becoming more sustainable and reach the goal of 49% waste reduction by 2030 compared to 2011
- local for local

Pain relievers

- Money savings for KCS for transport
- Produce local with distinct Miscanthus colour that is easy recognizable to seperate
- Provide sustainable alternative for plastic while reucing costs in transport
- A lof of benefits for KLM which adds to the fly responsibly campaign
- Material is biodegradable and when burned, not worsening the environment: CO_2 in = CO_2 out, netto the same
- Provide extra jobs for people with a distance to the market
- Diminishes environmntal impact and therefore concerns about it
- Fits to the new EU laws

Gains

- Fast and easy seperation of waste
- Reduce in transport costs
- KLM willing to change and pay more for sustain able alternatives

Good collaboration KLM/KCS

- Everything inhouse or local to have more controle
- Decrease in waste
- Lightweight and easy stackable products with the least amount of CO_2 impact to replace plastic.
- Good bond with people on the workfloor so they are motivated at work
- ICA waste treated the same as EU waste so more can be recycled.

Pains

- Paying to much for transporting waste
- Waste not seperated because employees are lazy
- Paying to much to other companies while they could do it themselves much cheaper
- Crew not willing to seperate because of a lack of time
- A bad collaboration between KCS and KLM and therefore KLM not listening to the advice of KCS
- When self designed machines are not working and waste is not seperated
- FIlling trollies does not go fast enough and arrive late to the aircraft
- KLM not willing to pay more for a sustainable alternative packaging
- Category 1 waste is burned and cannot be seperated

Jobs

- Try to do everything inhouse to save costs on transport
- Feel listenend to by KLM
- Seperate incomming waste from airplanes from KLM
- Distributing food for airplanes from KLM
- Filling trollies that will be loaded in airplanes in a limited time
- Make innovations in seperating waste more effectively and effieciently
- Reduce waste by buying in more responsible
- Gaining a sustainable appearance by separating waste
- Give advice to KLM what to buy in terms of materials
- Employ people with a disadvantage position to the labour market
- Make KLM aware of the amount of food wasted
- Talk to crew to instruct them how to seperate waste

10.9 Conclusion

When looking at the four design artefacts and different analysis that have been done such as the LCA, some key takeaways need to be considered to answer the design challenge:

Design a circular innovation strategy for Miscanthus based packaging at Schiphol, with a local for local approach, taking into consideration the complex system of papermaking

To fit within the local for local principle, the most fitting production method is mechanical pulping. In the short term, mechanical pulping can be done by establishing a partnership with for example Huhtamaki in the north of the Netherlands, in the longer term is it possible to build an own facility for mechanical pulping. The design artefacts show that both mechanically pulped artefacts (sandwich box and beauty case) have a large enough batch size to be covered with the current supply of Miscanthus and can, therefore, be implemented within a few years. Besides, the LCA can be concluded that mechanical pulping has a lower environmental impact compared to chemical pulping.

From the harris profile, it becomes clear that the beauty case and the blanket wrapper have the highest ranking when checked with the criteria. This can be explained by the fact that the other two design artefacts require a non-sustainable coating.

Everything combined shows that artefact 4, the beauty case is the best choice and fits the best with the design challenge. It can be manufactured using mechanical pulping, it does not require an additional non-sustainable coating and it solves a waste problem for KCS to reduce the number of beauty cases that are non-recyclable and are currently incinerated. For the longer-term (5 to 10 years), the sandwich box can be a good second product because then some experience is gained with producing Miscanthus based packaging, some revenues have been generated from the sales of the beauty cases that can be used for testing the sandwich box for food safety and adding the necessary certificates for food packaging and within the longer time it is also possible to develop a sustainable alternative for a coating for the sandwich box, instead of a fossil one. The blanket wrapper is not a good option to choose because currently, the production of Miscanthus is not high enough to produce enough volume, this can be solved by increasing the hectares in the Haarlemmermeer but it would take three years to gain maximum yield and by that time, it is expected that KLM has already another alternative since they are now already looking for an alternative for the plastic wrapper. Importing Miscanthus from abroad could be a solution in reaching the right amount of Miscanthus but the blanket wrapper would not be produced locally in this case. Also, since chemical pulping cannot be done in the Netherlands. The coffee cup has the same problem, although there is enough Miscanthus in the Haarlemmermeer, it still needs to be pulped abroad.

FUTURE AND CONCLUSION

The last phase of this thesis looks towards the future and concludes the research done. A short-term implementation will be presented, different product life cycles will be analysed and lastly, a roadmap towards 2035 will be presented. This chapter will end with a discussion and a personal reflection.

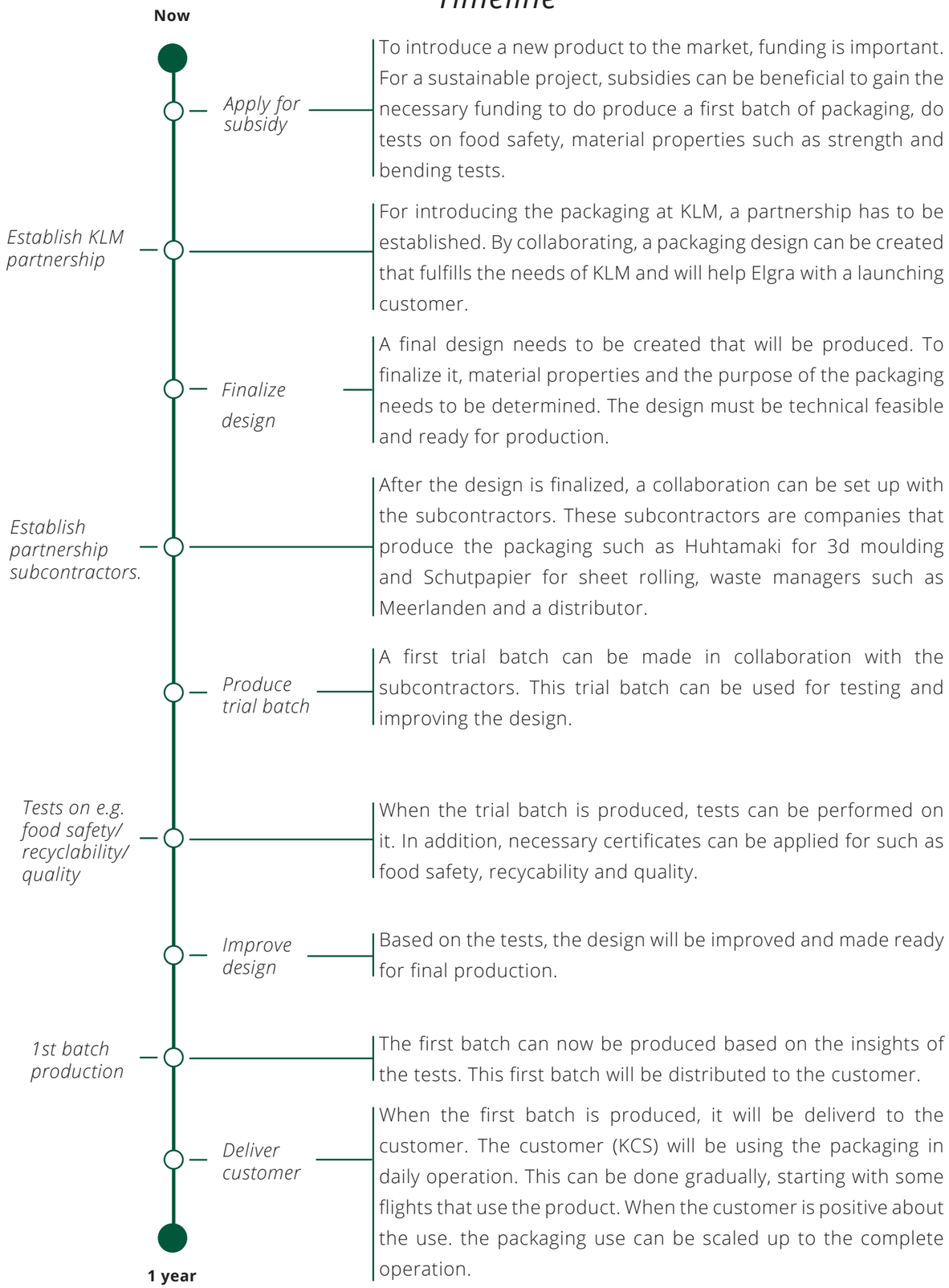
Chapter 11 |

IMPLEMENTATION PLAN

11.1 Implementation timeline

To look at the implementation of the design artefacts, a timeline has been constructed of the different steps that need to be taken to implement a Miscanthus based packaging. Each step is discussed on the next page. The steps on the timeline are based on the early stages of the roadmap and are determined together with Elgra and employees from KCPK.

Implementation Timeline



11.2 Product Life Cycle scenario's

To create Miscanthus based packaging, there are three possible life cycle scenarios. The difference between life cycles is the production method and the end of life. The first product life cycle explains the steps when chemical pulping is implemented and shows an additional cycle for the extracted lignin, the second product life cycle shows Miscanthus packaging being made with mechanical pulping where the collected products at the end of the life cycle entering a new cycle and cascading as an insulation material. The last product life cycle explores the possibility of producing Miscanthus packaging abroad in the short term and local in the long term. It is relevant for the business model and the roadmap to consider which product life cycle is the most relevant for the short and the long term.

11.2.1 Product life cycle 1: Utilising all components in the Miscanthus crop

The first product life cycle (Figure 29) is the most complicated one. It shows two circles, the outer black circle shows the life cycle of cellulose used for paper production, the inner blue circle shows the life cycle of lignin used for biofuel. In this scenario, the raw Miscanthus is chemically treated to extract both lignin and cellulose. Both components of the plant have their separate life cycles. Setting up a chemical pulping facility in the Netherlands will not be viable because it would require large investments and it should provide with at least a million tonne of pulp per year (while there is currently only 2000 ton raw Miscanthus available) to be able to become viable according to the director of KCPK, therefore this needs to be done at an existing chemical pulping plant. The locations of the chemical pulping facility vary between Scandinavia, Germany or Austria, there is no chemical pulping facility in the Netherlands.

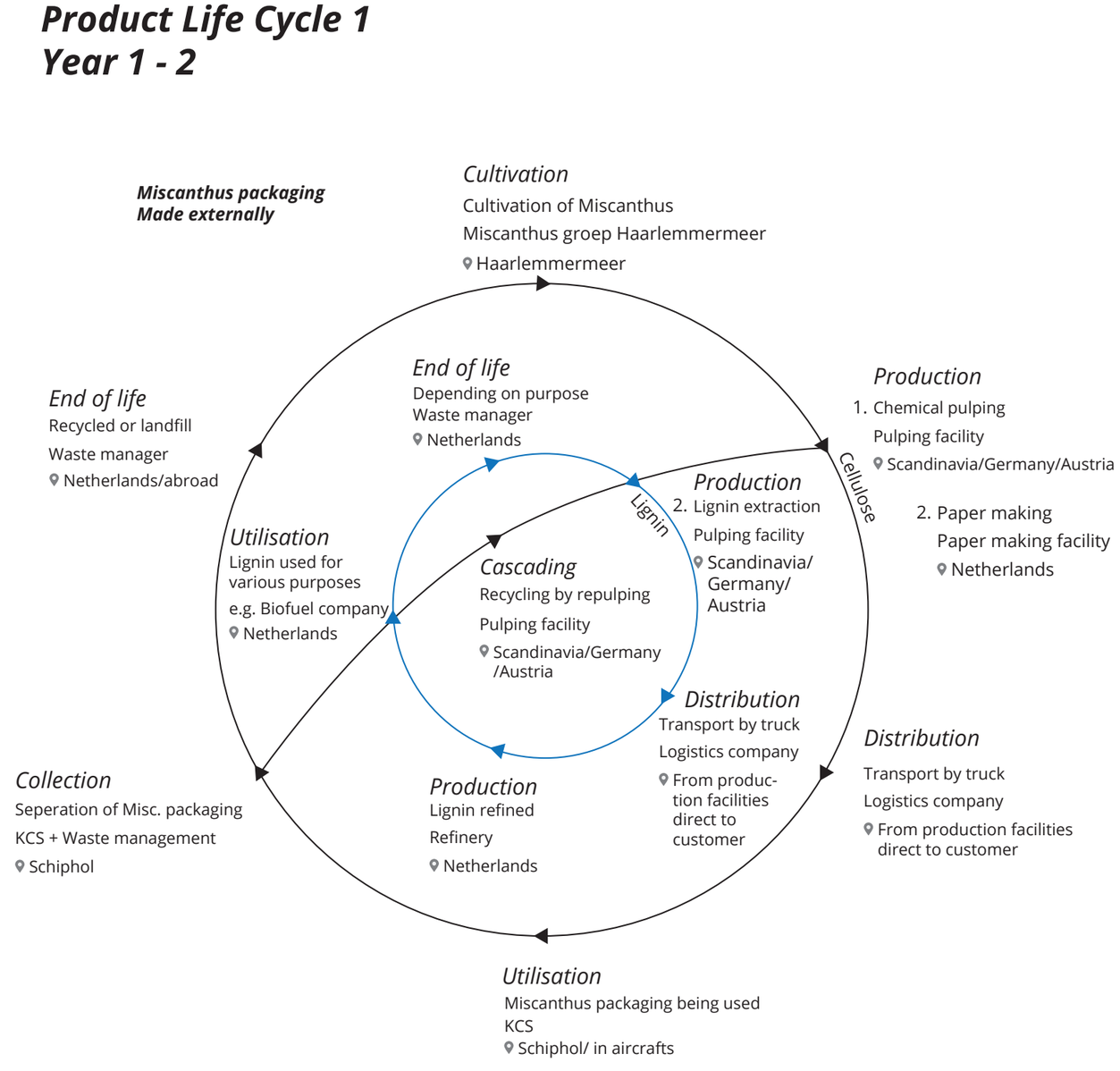
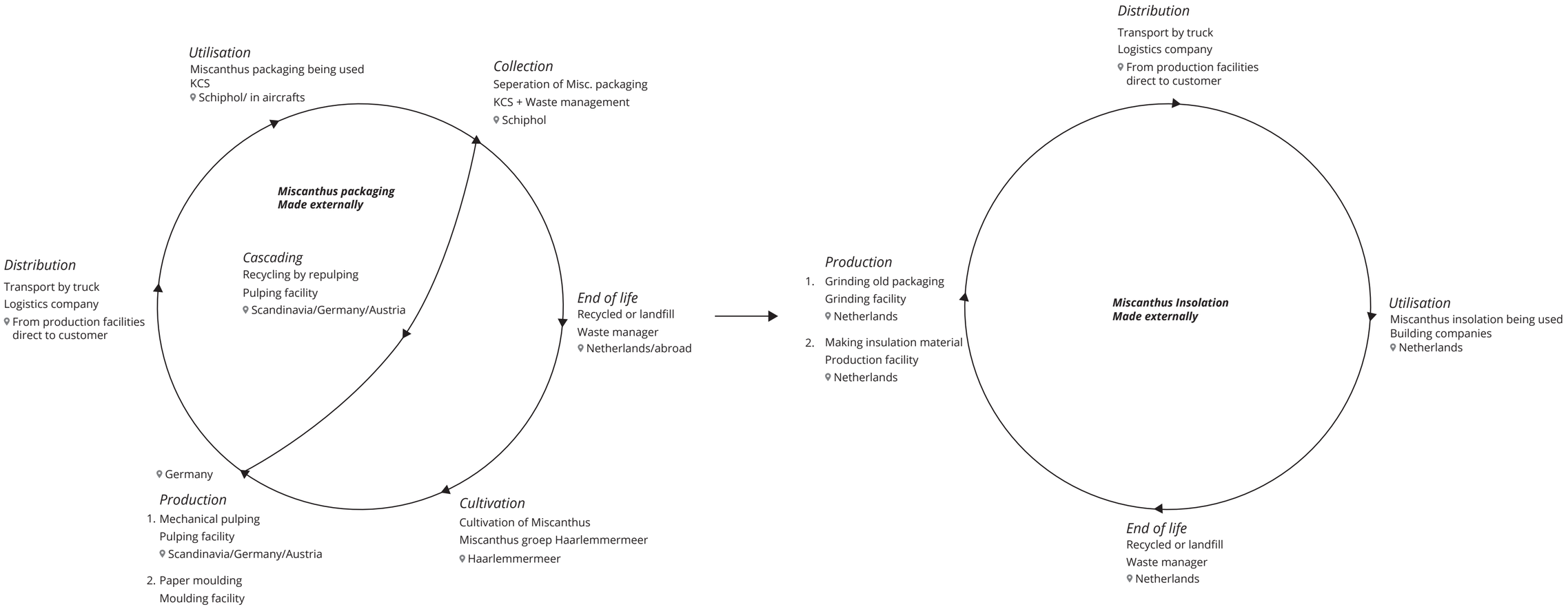


Figure 29: Product life cycle 1

11.2.2 Product life cycle 2: Cascading Miscanthus packaging

The second product life cycle (Figure XX) shows a scenario where the old Miscanthus products are recycled and enter a second loop where they are utilised for another purpose. In this case, the Miscanthus packaging is made at external paper making factories mechanically and moulded to a 3D product. This is chosen because for Miscanthus to be recycled into another product (not packaging), the quality of the packaging does not matter. Mechanical pulping results in a lower quality product. Besides, the lignin which is still contained within the pulp because it is not extracted will provide additional benefits for a next product life cycle loop such as adding extra strength (de Jong, G, personal communication, 2019).

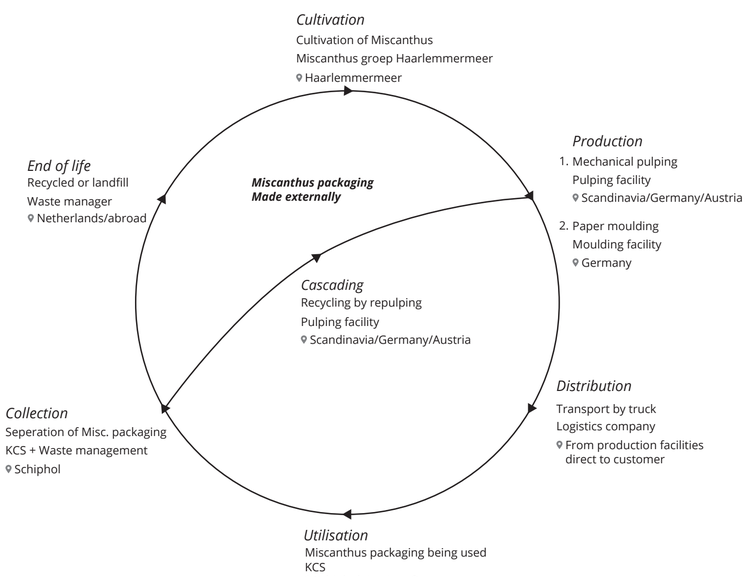
Product Life Cycle 2
Year 1 - 2



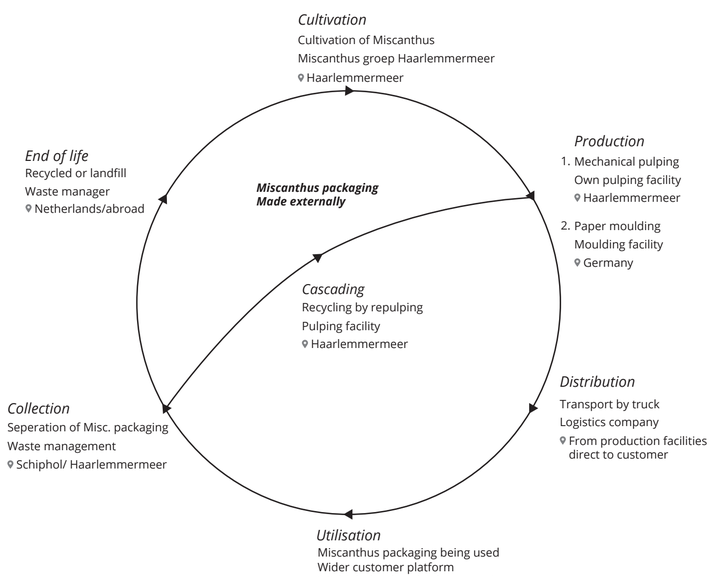
11.2.3 Product life cycle 3: Moving production from abroad to local

The last product life cycle scenario (Figure XX) shows multiple year plans. The first years, the Miscanthus packaging is produced externally at partnering companies. From the fifth year, the pulping will be done inhouse and from ten years from now, everything will be done internally. This product scenario can be used in combination with the product life cycle scenario 2, however, paper products are usually recycled and made into new paper products. Every recycling cycle creates shorter fibres, eventually resulting in them completely dissolving in water.

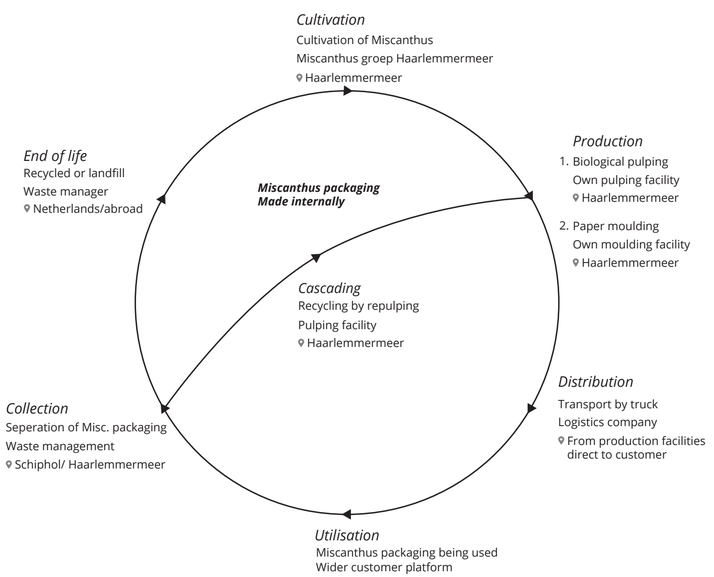
Product Life Cycle 3a
Year 1 - 2



Product Life Cycle 3b
Year 5



Product Life Cycle 3c
Year 15



11.2.4 Conclusion

By studying the three product life cycle scenario's, scenario 3 is the most likely to be implemented. This is because the investment costs at the first cycle begin low since no own production facilities are needed. Besides, the products are mechanically pulped and then moulded into a 3D product packaging. The products can be 100% recycled to new Miscanthus based packaging when they are collected. Also, the minimum batch size for mechanically pulping is 2000 tonne per year, which is reachable when looking at the current cultivation yield each year. Disadvantages of the first product life cycle, where the lignin is also extracted, is that this is not possible for a smaller scale production (Hooimeijer, A, personal communication, 2019). Besides, since chemical pulping is not done in the Netherlands, the local for local aspect will also be lost to some extent because the pulp needs to be transported to the production facilities.

For the second product life cycle, where the packaging is cascading to another purpose such as wall insulation, or other innovations for recycled paper, the disadvantage is that Miscanthus has relatively long fibres compared to wood (Section 2.1.1), it is a waste of the high-quality material to place it in a product that is likely to stay there for a long time while it can be recycled to new packaging more often.

Therefore, for the business model and the roadmap, product life cycle three that explains a three-stage time plan will be used.

11.3 LCA: Local for Local

The product life cycles described in Section XX, discuss the difference between producing Miscanthus local or abroad. To get a better understanding of the difference in environmental impact, a second fast track LCA has been performed. This LCA builds further on the LCA made for the design artefacts in Section XX. It only looks at artefact 2, the sandwich box and 4, the beauty case because they are both mechanically pulped. For producing packaging locally instead of abroad, it is only possible to mechanically pulp and bio pulp. Chemical pulp would require such large investments and expert knowledge that it would not be viable (Hooimeijer, A, personal communication 2019). The method of the LCA and all the other metrics are the same as used in Section 10.7 and will not be repeated in this section. In Appendix Y, the calculations can be found.

11.3.1 Results

From the results can be seen that there is no (significant) difference between internal or external production. This is probably because transport contributes only ~16% to the total eco-costs. A difference in transport distance does not bring a significantly better environmental impact. Although, when looked at the local for local aspect on system level, it is beneficial for the environment since Miscanthus has many benefits for its environment (the airport) and building a production facility close to the Miscanthus cultivation creates jobs for the local community for example.

11.4 Sustainable Development Goals

As already discussed in Section 1.1, Miscanthus based packaging help in reaching sustainable development goals (SDGs) set out by the United Nations. By doing desk research and comparing the different SGDs with their accompanying tasks, five goals have been selected where Miscanthus based packaging contributes to. This paragraph explains the goals and how Miscanthus based packaging contributes to it.

Figure 30: Goal 9 (United Nations, 2019b)

This goal (Figure 30) is about finding innovative ways to repurpose old material and to increase the efficiency of production processes. It aims to promote sustainable industrialization with high efficiency and smart use of the resources. Miscanthus based packaging contributes to this because it is a new and sustainable material, where there is flexibility to set up a business that operates under a circular mindset.

Figure 31: Goal 11 (United Nations, 2019a)

This goal (Figure 31) aims to improve city life by reducing pollution and poverty. Also focussing on housing and waste management. In 2030, more and more people will be living in the city so this goal will become more important every year. Goal 11 has set the target that by 2030 to reduce the environmental impact of cities by looking at air quality and waste management. This means that Miscanthus cultivation contributes to that because of its possibility to absorb large quantities of CO2 and by creating a compostable alternative for plastic packaging. For Miscanthus to stay in the Haarlemmermeer (close to Amsterdam), a highly-populated area, it must help in reaching the targets set by goal 11.

Goal 12 (Figure 32) is about the sustainable consumption and production of resources. This plays into the need for circularity as well. It aims at doing more and better with fewer resources. To reformulate, this goal is about increasing efficiency. A target for reaching this goal states that by 2030, sustainable management and efficient use of natural resources is achieved. For Miscanthus (cultivation) and packaging production, this means that it is important to monitor the supply and demand and not overproduce. Also, the efficiency of the production of Miscanthus based products needs to be monitored to reach this target. Besides, goal 12 states that by 2030, there needs to be a substantial reduction of waste generation through prevention, reduction, recycling and reuse. When looking at this target, Miscanthus can contribute to this by creating a packaging that is easy to recycle and that aims to stay as long in use as possible.

Figure 32: Goal 12 (United Nations, 2019d)

Figure 33: Goal 13 (United Nations, 2019e)

The climate action goal (Figure 33) speaks of the changes that need to be made to make sure the climate does not change any further. The targets are among others to strengthen the climate change measures into national policies, strategies and planning. Miscanthus based packaging contributes by this by providing a strategy that is designed to make sure that the production and sales of Miscanthus products have the least possible impact on the environment.

Goal 15 (Figure 34) speaks of increasing forests to protect biodiversity and provide food, security and shelter. Also, forests absorb high levels of CO2 which helps in the reduction of it. This goal also applies to Miscanthus. Since it has the same rate of absorbing CO2 as trees and it protects biodiversity (Semere, & Slater, 2007). A target that is set to reach this goal is that by 2030 that degraded land and soil will be combated to achieve a land degradation-neutral world. Currently, there is an initiative in Europe where 7 countries participate in to use Miscanthus and hemp to be cultivated on contaminated soil to increase the production of sustainable raw materials. This is already in line with the target to have a degradation-neutral world.

Figure 34: Goal 15 (United Nations, 2019c)

Another target set by the UN to reach goal 15 is to increase biodiversity. According to Semere, & Slater (2007) (Section XX), Miscanthus fields aid in increasing biodiversity on farmland, therefore the crop also aids to this target.

11.5 Business model canvas

To make sure the Miscanthus based packaging is implemented using the right strategic choices, a business model canvas has been filled in (Figure 35). The business model canvas (Osterwalder & Pigneur, 2010) shows the business model of Miscanthus based packaging on one page making it concrete. Since the environmental impact is such an important factor for Miscanthus packaging and part of the strategy as well, an extra element is added to the canvas. This describes the additional benefits for the environment that helps in making the business model stronger because it shows potential buying companies, the environmental benefits of the packaging. Besides, the reducing emissions at certain parts of the value chain can make the business model stronger because costs are saved in for example transport and CO2 emission costs.

The strategic choices that are made in the canvas, decisions are made based on the previous chapters. These decisions are explained below and included in the canvas (Figure 35) and are based on the criteria stated in Section 6.2.

11.5.1 Closed system

The market criteria showed that Miscanthus based packaging needs to be introduced in a closed system (Section 6.2). This closed system is in place at KCS (Section 8). For the business model, it is important to include the collection by KCS and what happens with the packaging after it is collected. The design artefacts already explain the collection and the repulping of the Miscanthus based packaging for recycling (Section 10).

Local for local

Throughout the thesis, it becomes clear that local for local is an important factor to consider when implementing Miscanthus based packaging in the market. From the comparison LCA (Section 10.7), it shows that producing the Miscanthus based packaging locally, it reduces the environmental impact. In addition, from the context analysis (Section 8), the Miscanthus crops have a positive impact on their environment in terms of sustainable cultivation. Furthermore, transport costs are high currently (Rietveld, E, Personal communication, 2019 (Appendix W)), saving costs by producing locally can decrease the product price, making the Miscanthus based packaging price competitive to other sustainable packaging types.

11.5.2 Closed system

For Miscanthus based packaging there must be a constant demand (Section 6.2). This demand is present at KCS, the travel industry is growing and KCS provides Miscanthus based packaging the opportunity to scale up matching the speed of increasing the production of the Miscanthus based packaging. This is also included in the roadmap (Section 12).

11.5.3 Paper industry

The artefacts in combination with the research on the technical specification of Miscanthus based packaging (Section 2.1.4 and 10 respectively) showed that for the mechanically pulped and 3D moulded packaging, recycled paper is necessary to achieve the necessary strength for the packaging. This is relevant for both the business model and the roadmap.

Mechanical pulping

Due to the local for local nature of the Miscanthus based packaging, the choice for pulping falls on mechanical pulping instead of chemical pulping. This is because, for chemical pulping, it is not possible to do that in the Netherlands (Adriaanse, M, Hooimeijer, A, personal communication, 2019). Besides, the comparison of the different artefacts based on LCA shows that mechanical pulping has a lower environmental impact. When it is chosen to do chemical pulping, it is important to consider that collaborations need to be established with chemical pulpers abroad in for example Germany or Scandinavia.

For the roadmap, when mechanical pulping is considered and for the short term, this needs to be done at a company such as Huhtamaki, located in Friesland (NL). They are specialised in producing packaging and offer the facilities of mechanically pulped

packaging for food and non-food products (Section 4.1.1 explains the company Huhtamaki).

Important to consider is that tests have shown that mechanically pulped Miscanthus needs 50% extra recycled paper to produce a material that has enough strength to become a paper packaging (Appendix C). For the roadmap, the research time for optimising the miscanthus pulp 'recipe' needs to be taken into account.

3D moulding

From the comparison of the design artefacts (Section 10) and the possibilities of the manufacturing process, 3D moulding is the preferred production method. In combination with mechanical pulping, it is beneficial for the packaging to be 3D moulded because the quality of the pulp is lower. For sheet rolling, mechanical pulping is also possible, but the result will not be of high quality, it is expected that it results in a not so smooth material (for example a rough-surfaced coffee cup). Besides, 3D moulding is for small batches viable, while for sheet rolling, larger batches are required to make the product viable (economies of scale). For the roadmap, it is important to notice that when the Miscanthus based packaging is implemented at first, the 3D moulding should be done by a subcontractor (e.g. Huhtamaki), in the longer the production facility can be done by Elgra themselves because then the funding is present to build a new facility.

Key Partners

Subcontractors of pulping and moulding facilities,
e.g. Huhtamaki

KCS for developing products

Waste manager that repulps Miscanthus products,
e.g. Meerlanden

Concrete production facility to buy Miscanthus for concrete reinformement

Insulation manufacturer that buys of old Miscanthus products that are not suitable for repulping to produce insulation.

Key Activities

Creating Miscanthus based moulded packaging

Maintaining partnerships

Networking with hospitality industry and paper industry

Selling Miscanthus products, packaging and other already existing Miscanthus applications.

Key Resources

Miscanthus

Storing facility

Fundings

Investments

In the longer term, production facility.

Value Proposition

See value proposition canvas, Section XX.

Customer Relationships

B2B, a sales representative

Customer Segments

KCS

Catering companies of airlines

See value proposition canvas

Channels

Direct sales.

Awareness: Is created by having meetings with employees that have the means to make decisions about packaging materials.

Evaluation: Propose a business plan and show costs and CO2 impact compared to regular packaging.

Evaluation: Propose a business plan and show costs and CO2 impact compared to regular packaging.

Purchase: Tenders and direct sales

Distribution: Bring product to p.o.s.

Environmental impact

Minimized by local for local

Minimized by mechanical pulping

Miscanthus packaging is carbon neutral

Miscanthus has environmental benefits for airport.

Cost structure

Value driven

Economies of scope

Revenue Streams

Reocurring revenue streams from ongoing payments

KCS pays for the goods they need and Elgra brings the goods to KCS. KCS makes sure the goods are collected in a seperate waste stream.

Volume dependend.

Figure 35: Business model canvas

CHAPTER 12

ROADMAP

To map the future steps of Miscanthus based packaging, a roadmap is formulated. According to Simonse, Iwanicka, & Whelton (2018): “Roadmapping is a visual portrayal of design innovation elements on a timeline”. A roadmap can consist of many different elements (Simonse et al, 2018), this roadmap consists out of 5 layers, each having its focus. The roadmap offers a tactical plan to illustrate the necessary steps to realise the future vision (Simonse et al., 2018). This roadmap for Miscanthus based packaging is created together with the company owner of Elgra. The reason for constructing the roadmap in collaboration with Elgra is to form a complete roadmap validated with the capabilities of Elgra. The five elements that are chosen to incorporate in the roadmap are:

- Trends
- Technological advancements
- Financial capabilities
- Necessary resources
- Collaborations

The elements are chosen because they each represent a part of the design thinking model (Figure XX). Feasibility is represented in the technological layer, viability is represented in the financial, resources and collaboration layer and desirability is represented in the trends layer. Besides, all these elements have been investigated in this thesis. To enable Elgra to express their needs, boundary objects were created to stimulate the conversation. A boundary object is an object that helps people from different fields come to a common understanding and to be able to work together on a new project (Star & Griesemer, 1989). In this case, the boundary object were canvasses designed to collaboratively design a roadmap. The canvasses can be found in Appendix Z. The incorporated elements such as the trends and the technological advancements in the roadmap are based on insights found during the research from the context exploring phase of this thesis. The roadmap can be seen on page 167. The next pages show a more detailed explanation of each layer.

12.1 Future Vision

The first stage of designing a roadmap is creating a future vision (Simonse et al., 2018). For this roadmap, the future vision is formulated as:

Contributing to the new circular economy by reducing the amount of single-use plastic with the use of an annual crop Miscanthus.

This future vision will be the end goal of the roadmap. The rest of the roadmap is divided into three different horizons, each overlapping. The overlap displays a transition phase from one horizon to the next and is chosen to do because around that time, certain milestones need to be reached and the next phase requires new strategic decisions that need to be taken. Each horizon has its vision to show the main purpose of that horizon. The third horizon aims to end with a fully operating production facility of Miscanthus based packaging with a larger variety of customers. The roadmap ends in 2035, this timing is chosen because it is the most realistic time to reach the third horizon, this is based on the ambitions of Elgra and the time pacing of the technological advances and possibilities of acquiring the necessary funding.

12.2 Roadmap layers

12.2.1 Trends

The first layer of the roadmap are the trends. These trends are selected on relevancy for the rest of the processes and of innovations that need to be considered in the future. They are the selected trend opportunities from Section 4.2, without specific target group trend (Trend 1) because the target market is KCS and the provided strategy is B2B, meaning that Elgra has no direct influence on the target group of KCS. Trend 5, the contradicting trends about the amount of packaging is also not applicable for this roadmap because the type of packaging KCS provides to its customers such as sandwich boxes and coffee cups are necessary packaging types that cannot be eliminated. The other trends that the trend layer does show are:

- Sustainability laws
- Travel industry is largest growing sector (globalisation)
- Sustainability going mainstream

12.2.2 Technology

The second layer, the technology layer looks at what technological advances are necessary to grow the business. The first horizon is mainly operating with subcontractors. Here raw Miscanthus will be transported to the subcontractors who create Miscanthus packaging. From the second horizon onwards, Elgra starts investing into its own machinery, professionalising the business and moving production from external contractors to inhouse. The last horizon shows starting to pulp fibres using biopulping (Appendix E) and starting to extract chemicals from Miscanthus for high grade applications such as creating bioplastic from Miscanthus.

12.2.3 Financial

The third layer looks at financial resources that are necessary and how Elgra is planning on gaining those financial resources. Especially for a start-up that has at first no profit from their products, it is important to consider when certain investments need to be made in order to be able to finance possible expansion of the business. During the first horizon, a subsidy is arranged to start developing the first product and to expand the product line. In the second horizon, investors need to be found that help in funding the production facilities that need to be built in the third horizon. The firs actual profit is estimated to occur in the second horizon, when the first product is widely implemented, and other potential customers can see the added value of a Miscanthus based packaging. In the third horizon, a second subsidy is applied for, to start implementing a biopulping facility that will operate next to the mechanical pulping facility.

12.2.4 Resources

The fourth layer is the resources layer. This layer looks at the product portfolio and when new products should be introduced. Resources also means acquiring the right intellectual resources, therefore also doing research on several topics are included in this layer. The first horizon is mainly focussing on establishing a market for the first product that is sold. Later, the product line will expand mainly because of the technological advancements that are made within the business. From the third horizon, the business will start orienting on the utilisation of other sustainable crops that can be used for sustainable packaging to expand the company even further.

12.2.5 Collaborations

The last layer shows all necessary collaborations to make the company operational. Collaborations are made with subcontractors and Millvision in the first horizon who will be providing the research and development of new Miscanthus based packaging. In addition, shows also the other collaborations that are currently in place. From the second horizon onwards, the subcontractors for pulping will no longer be necessary because Elgra will start in doing it on their own.

Horizon 1

Setting up a viable business with Miscanthus packaging at its core

Horizon 2

Learn from horizon 1 and use these insights to bridge to horizon 3

Horizon 3

Professionalising current processes and businesses

Vision

Contributing to the new circular economy by reducing the amount of single-use plastic with the use of an annual crop Miscanthus.

Now 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035

Trends

- Sustainability laws: Start single-use plastic ban; Dutch gov. additional single use plastic regulations; CO_2 levels 49% lower
- Travel industry: Travel industry is largest growing sector
- Sust. = mainstream: Sustainability is going mainstream

Technology

- External production: Subcontractors
- Grinding: Buy grinding equipment; Grinding using own equipment
- Mechanical pulping: Use 50% recycled paper/50% misc pulp; Buy pulping equipment; Mechanical pulping using own equipment
- Biopulping: First biopulping tests on Misc.; Large scale biopulping tests; Biopulping implemented in the business
- Moulding: Buy moulding equipment; Moulding using own equipment
- Chemical pulping: Extracting chemicals

Financial

- Subsidy: First subsidy; Second subsidy
- Investments: Investors
- Sales: Sales from products
- Profit: Estimate of first profit
- Loans: Bank loans

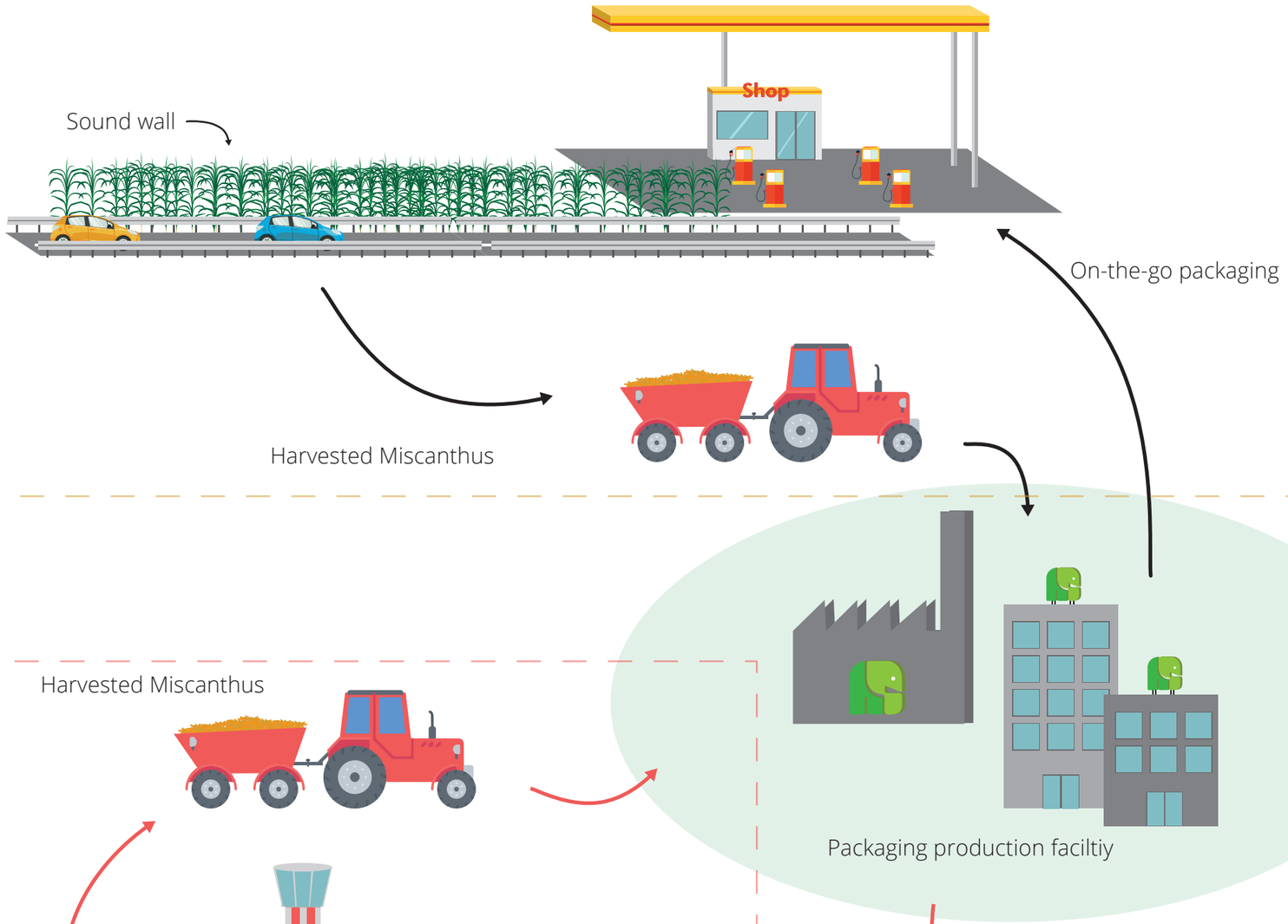
Resources

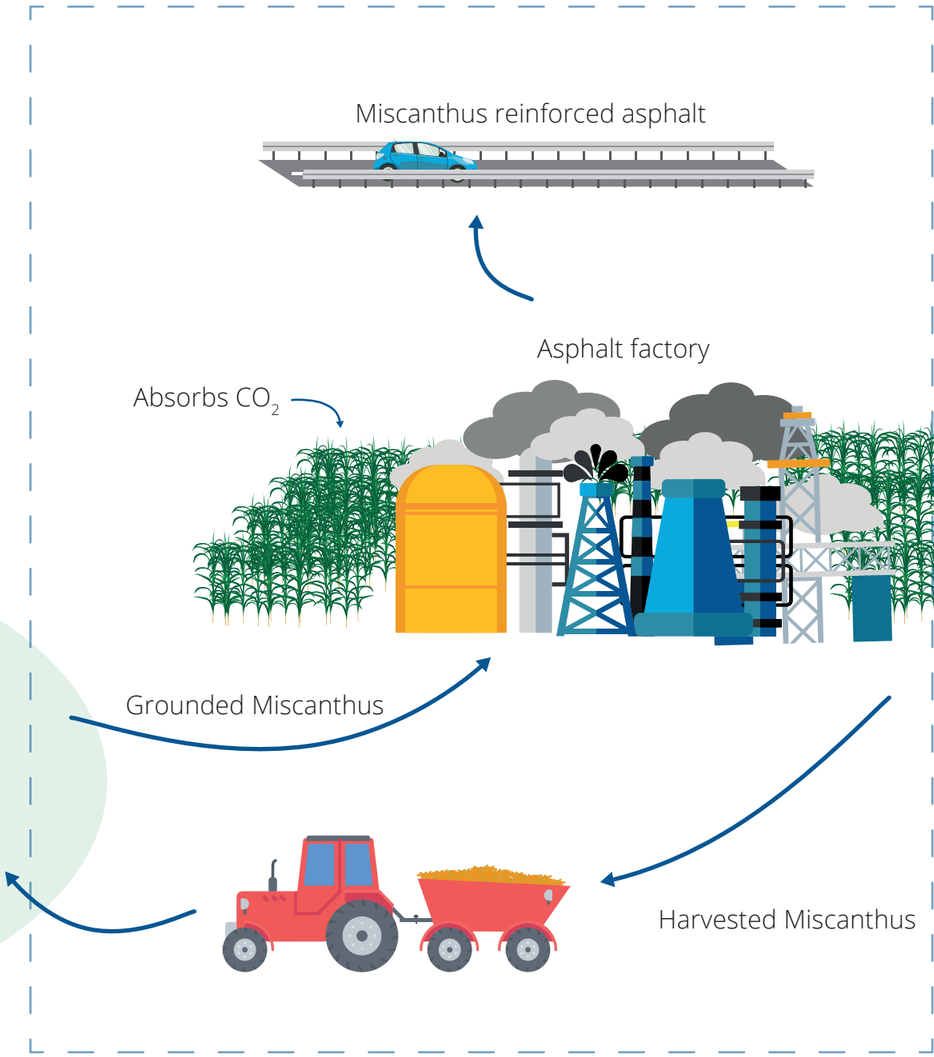
- Products: First product; Expanding product line
- Research: Researching sust. alternative PE laminate; Optimize mechanical pulp without recycled paper; Orientation on other crops
- Expanding business: Expanding business to other local for local opportunities; Expanding business to other crops
- Biopulping: Fungi for biopulping

Collaboratoins

- Miscanthus Groep: Cultivate Miscanthus; Scale up Miscanthus cultivation; Cultivate Miscanthus and other alternative fibre crops
- Parters of finance: Partners who arrange administration and finance
- Business partner Elgra: Business partner within Elgra
- Millvision: Research sust. alternative PE lamnate; Establish R&D department; Research other alternative crop potential; Research extracting chemicals Misc.
- Subcontractors: Establish partnership; Maintain partnerthip; Establish partnership with chemical pulping plant
- Bioclear Earth: Initialize biopulping project; Research biopulping possibilities on large scale

LOCAL FOR LOCAL





Three local for local ideas are presented here that can be a future vision for Miscanthus products, there are ofcourse many more options, however these are choosen as an illustration of what is possible in the long term. The first on the upper left part shows Miscanthus being used as a sound wall because of its sound dampening capabilities, used to create packaging for on-the-go food packaging. On the right side of the visual, Miscanthus is used as a CO_2 capturing for asphalt production and then used as reinforcement inside the asphalt as a sustainable alterantive to bitumen. On the left side at the bottom, the vision displays a similar proposition as done in this thesis where Miscanthus is planted around other airport in the Netherlands (in this case Rotterdam airport) and used for sustainable packaging. All these future scenarios can be further investicated as local for local initiatives.

Chapter 13 | DISCUSSION

This chapter concludes the thesis and reviews how the research questions and design challenge are answered, besides, it discusses the next steps that need to be considered for implementing the proposed strategy for Miscanthus based packaging. The limitations of this thesis will be discussed, and recommendations will be given on further research. Lastly, a general conclusion on the project and a personal reflection will be given.

13.1 Discussion

This Section discusses the project and how the research questions are answered, it discussed that the next steps that need to be taken and how this contributes to new knowledge. Furthermore, it discusses the project and research limitations and gives recommendations for future research.

13.2.1 Discussion of the project

The project's purpose was finding a high-grade purpose for Miscanthus as a crop. Currently, Miscanthus only used for floor bedding at festivals or petting zoos which is a low-grade application. Miscanthus has however proven to be the potential to be the main resource for a paper packaging material that can be used as a sustainable alternative for single-use plastic packaging. By creating paper from Miscanthus, the fibres are given a higher-grade purpose and stay in use much longer. By introducing Miscanthus based paper in a circular system, the fibres can be recycled often, extending the lifespan of the resource. With this, the following research questions are formulated:

RQ1: How can sustainable packaging made from Miscanthus be developed using a circular innovation strategy?

Additional to this, a second research question has been formulated because there was not yet a specific market for Miscanthus based packaging in mind:

RQ2: How to position a new type of sustainable packaging made from Miscanthus on an existing market?

To answer these two research questions, an extensive context exploring phase was done to get a better understanding of Miscanthus as a crop, paper marking and market analysis to identify a potential market for Miscanthus based packaging. As a result of this analysis, three market criteria have been defined that measure whether a certain market was interesting for Miscanthus based packaging:

Closed systems have a controlled environment

This market criterion helps in answering RQ1 by determining what aspects are necessary for a Miscanthus based packaging to be implemented in a closed system. These aspects are having a controlled market where the inflow and outflow of Miscanthus packaging are regulated resulting in a separate waste stream. This leads to the possibility of used Miscanthus packaging being recycled to new Miscanthus packaging. Besides, a controlled environment and a closed system, prevent Miscanthus based packaging getting lost in the general waste stream and eventually being incinerated.

For answering RQ2, this criterion is relevant and shows that for positioning Miscanthus based packaging on an existing market, partnerships with several parties are needed to achieve a closed system. The companies that are needed as partners are waste managers to repulp the Miscanthus packaging for new products, but also the company that buys Miscanthus packaging. They need to be able to separate the Miscanthus packaging from the other waste streams and make sure it can be picked up by for example the waste manager.

The last important insights that fall within this criteria is the local for local aspects. For RQ2, the selected market can benefit from the environmental benefits of Miscanthus. Miscanthus as a crop has many benefits for its environment such as capturing dust particles, increase biodiversity and for Schiphol, hinder geese and dampening sound. For Miscanthus packaging, local for local is important because it helps in creating a closed system by being able to deliver and manufacture Miscanthus packaging close to the client. This reduces costs for transportation and environmental impact from transportation.

Constant demand

For answering RQ2, it is important to consider that Miscanthus based packaging is introduced in a market that has constant demand and that is not trend sensitive. The constant demand ensures that a steady supply of Miscanthus can be given and that the cultivation can steadily be increased when the demand increases. Miscanthus takes three years to reach maximum yield and maintains this yield each year for 25 years, so a sudden increase or decrease in demand is not beneficial. This is closely related to the fact that Miscanthus packaging is preferably not trend sensitive since a trend sensitive packaging can go with a sudden increase or decrease of demand.

The complex industry of paper

The last market criteria, the selected market needs to comply to, helps in answering RQ1 by looking at the development of paper packaging. Findings from the exploration phase show that to produce Miscanthus based packaging, four different routes can be taken, which are chemical pulping, mechanical pulping, sheet rolling or 3D moulding. Besides, before producing the packaging, it is important to consider the purpose of the packaging, this can either be for food, or for non-food. Both require different production steps which are adding

a coating and having all the necessary certification to be able to hold food.

This criterion help also in answering RQ2 because for Miscanthus packaging it is important to give it a distinctive positioning compared to its competitors. This is achieved by having a local for local system in place where the Miscanthus cultivated, produced and distributed locally.

Based on these three criteria, the market of Schiphol has been selected. The airport industry shows the potential to for being a closed system, Miscanthus grows close to Schiphol so a local for local system can be put in place, in addition, some initial research showed that there is a constant demand for Miscanthus packaging at this market and it provides the possibility to introduce the different types of produced Miscanthus packaging. To translate the research questions to a specific market, a design challenge is formulated:

Design a circular innovation strategy for Miscanthus based packaging at Schiphol, with a local for local approach, taking into consideration the complex system of papermaking.

To help to answer this design challenge, a deep dive into the market of Schiphol is done to test the assumption that Schiphol is an interesting market. This assumption was proved and KLM Catering Services (KCS) was selected as a potential to introduce Miscanthus packaging as a launching customer. As an answer to the design challenge, four different design artefacts were designed that show the different possible strategic directions that can be taken to introduce Miscanthus based packaging to the market. The analysis showed that the beauty case (artefact 4) is the most feasible to be implemented in the short term. The sandwich box (artefact 2) proved to be a good product to be implemented later in the roadmap because it requires additional research on finding a sustainable coating for food proof packaging. To complete the strategy for Miscanthus based packaging, several elements have been added. These elements will be separately discussed below.

A fast track LCA was performed, which showed that for environmental impact, the local for local approach is for Miscanthus packaging not necessarily the better option. Even though a lot of impact can be saved from transport when the packaging is produced and used locally, this does not affect the total environmental impact. However, when looking at a system level to the local for local aspect, there are many benefits such as KLM having fewer problems with geese who are hindered, the dust particles coming from emissions from aircrafts can be captured resulting in a cleaner environment in a polluted environment around the airport.

The business model canvas has been used to formulate a concrete business plan. The decisions made for the business plan is to introduce Miscanthus packaging in a closed system (Section 6.2), provide the packaging in a local for local system (Section 6.2). As a starting product, develop a mechanically pulped, 3D moulded, non-food packaging (Section 11..5).

Another element of the strategy is the implementation plan and the roadmap. The roadmap shows in a longer period the actions that need to be taken to reach the future vision of Elgra of having an own production facility for Miscanthus based packaging and offering local for local packaging solutions for companies in the Netherlands. The implementation plan shows the short-term actions that need to be taken to develop a Miscanthus based packaging for the launching customer (KCS). These actions are for example developing packaging design, producing the first batch and establishing partnerships with the necessary partners (e.g. production facilities and waste managers) to establishing a Miscanthus packaging.

Referring to the stated design challenge, the final circular innovation strategy has been designed for the market of Schiphol with a local for local approach, taking into consideration the different design routes that can be taken when producing a paper packaging based on Miscanthus. Value has been created with this strategy for Elgra as a company that wants to introduce Miscanthus based packaging on the market by giving them the necessary steps that need to be taken for implementation and by bringing them the theoretical knowledge for making informed decisions for future Miscanthus packaging development. For KCPK value has been created by providing them with a strategy for Miscanthus based packaging, showing that it is possible to develop a circular business model for Miscanthus based packaging and examining the possibilities and different design routes a Miscanthus packaging can take.

13.2.2 Next steps

After this thesis has been submitted, it is important for this circular innovation strategy that the right actions are taken for implementations. This Section will give three recommendations on the next steps that can be taken to implement the Miscanthus based packaging at KCS.

First, more research on the Miscanthus material needs to be done. It needs to be clear how Miscanthus pulp will form in industrial, large scale processes. Currently, 3D moulding Miscanthus packaging is only tested at a small scale (only 10 products have been made). Besides, the material has only been tested with the application in mind of becoming a green waste bin (Section XX), therefore, additional testing is needed for the production of Miscanthus based packaging.

The second step is developing a first trial batch of Miscanthus based packaging. When the initial lab tests are done and the Miscanthus pulp has the correct 'recipe' for 3D moulded packaging for example to create the KCS beauty case (artefact 4), a first larger-scale trial batch needs to be produced. To have the necessary funding to produce a trial batch of for example 1000 pieces, a (governmental) subsidy can be applied for. For the trial batch, it is necessary to establish a collaboration with a mechanical pulping facility, this can be for example Huhtamaki in Friesland. They know 3D pulp alternative fibres and have the resources to do a trial batch (Adriaanse, M, personal communication, 2019).

The last step is to establish a partnership with KCS/KLM and other subcontractors such as waste managers who can repulp Miscanthus for recycling. The product life cycle needs to be in place for Miscanthus packaging can be introduced to the market. Preferably, this step is done simultaneously to the previous two steps.

13.2.3 Contribution to new knowledge

This thesis contributes to new knowledge by proposing a literature-based circular strategy for introducing a packaging from an alternative fibre on the market, considering the different production methods of paper packaging and environmental impact. By outlining four different design artefacts, illustrating the different layers of packaging production, the possibilities for Miscanthus based packaging are structured and the advantages and disadvantages of choosing one direction or the other are examined. For this thesis, choosing a non-food, mechanically pulped, 3D moulded packaging was the best solution, for other types of packaging, a different route than described in this thesis might be more appropriate. Until now, only the possibilities of using Miscanthus for paper production have been examined in existing literature (Ververis et al., 2004; Cappelletto et al., 2000; Oggiano, Angelini, & Cappelletto, 1997; Marín, Sánchez, Arauzo, Fuertes, & Gonzalo, 2009) and not concretised to a real product packaging, taking into consideration the environmental impact, like is done in this thesis.

13.2.4 Limitations

During this thesis, an extensive literature review has been done and a lot of different information from different areas of expertise needed to be gathered to come to the final circular innovations strategy. This also comes together with some limitations. The available literature on Miscanthus, Miscanthus paper and the papermaking process was fragmented, sometimes it proved to be difficult to find all necessary information to get enough in-depth knowledge to design a circular innovation strategy. To validate the use of available literature, during the process, often the findings were checked with a specialist at KCPK and the faculty, however, there is still a chance that some literature is missed.

Another limitation is the fact that during this project, simultaneous research was done on the business aspects of Miscanthus packaging by Elgra. This resulted in new insights occurring during the project that would require large changes to the thesis. For example, at some point during the project, the decision was made to build the factory later in the roadmap instead of next year. This resulted in that the roadmap needed to be adjusted in the last moment. In addition to this was that during the project, the possibilities of bio pulping were explored and it proved to be an interesting

direction to look at. This meant that for the roadmap and the project to be completed, information about bio pulping needed to be acquired and included in the thesis.

Furthermore, at the start of the project, little to no material samples were present which were beneficial for understanding the possibilities of Miscanthus based packaging. Some of these samples had to be made by hand by the author to get a feel of the material and to interpret what possibilities there were. In addition to this lacking research on the material properties of the material made it sometimes difficult to determine the different possibilities. This was overcome by assuming that Miscanthus would behave similarly to regular paper, based on the little amount of literature that is currently present.

Furthermore, the assumption is made in this thesis that it is clear for companies and consumers to separate Miscanthus packaging in a separate waste stream and recognize it as sustainable packaging. However, literature has shown that to packaging to be recognized by consumers as sustainable and throw it in the right waste bin, a clear eco-label is necessary (Krah, Todorovic, & Magnier, 2019).

13.2.5 Future research

This thesis has contributed to the field of sustainable packaging design and packaging made from Miscanthus. For future research, recommendations are to explore the possibilities of applying this strategy on other alternative sustainable fibres for paper production, extrapolating the strategy to other sustainable crops. The literature review showed that other crops have similar mechanical properties to Miscanthus such as hemp or straw. Besides, it is recommended for future research to examine the possibilities for applying the Miscanthus circular packaging strategy for other local for local concepts. This thesis already provides some alternative scenario's in Section XX, however, these are not yet validated and are possible scenario's based on the insights from this thesis. Future research could focus on searching other markets and product possibilities for Miscanthus in local for local concept.

13.3 Personal reflection

At the start of this project, four personal learning goals were formulated. The learning goals are separately discussed:

1. I want to get a deeper and broader understanding of the circular economy.

This project helped me in getting a better understanding of the circular economy. I learned about the model from Ellen Macarthur and used this as a basis for my strategy. During my project, especially at the end, I noticed that I paid less attention to the collection part of the strategy, and when I noticed that, I focussed more on recycling in the business model and the described product life cycles to solve this. For the future, I will use this knowledge in my future career to design circular strategies that do not focus on take-make-dispose, have a circular approach.

2. I want to focus on having a good planning

During this thesis, I help up to my planning well. I did that by starting each week with creating a planning and finishing all the tasks that I had set for myself. This worked well and most of the time I finished all the tasks I wanted to do. However, for the longer term of the project, this approach did not work, I sometimes lost where I was working towards and was just doing random things that did not fit the overall line of the project. One of these things was experimenting with the Miscanthus paper. I wanted to do a user test, so I set up the test, asked participants and spend a whole week on it. In the end, the user test was not necessary for my whole project and the results were not useful. This was mainly since I just planned per week and was not working towards an end goal. For the future, I want to look more ahead and have sometimes a broader perspective on the project and sometimes zoom in for short-term planning.

3. I want to write less text and make use of more meaningful visuals, I tend to write a lot but in my graduation, I want to focus more on creating clear visuals based on the text.

This learning goal was unfortunately not met. I still wrote a long thesis with a lot of text and not that many visuals. This is probably because I did not give myself the time to create the necessary visuals to replace the text and focus more on getting the textual content complete and correct. I still believe that visuals instead of text are the best way to go and I will keep this in mind for further projects and try to write less.

4. Lastly, I want to use the methodologies I learned during previous projects, such as roadmapping, business case building and analysis methods such as SWOT and DEPEST.

The last learning goal was met. I did take the opportunity to use my skills and apply the right methods for the right part of the project. I performed a SWOT analysis to find market criteria and concluded this thesis with a roadmap. For the future, I want to keep using different methodologies to help me in building strong strategies.

In addition to the learning goals, there is one more point I want to reflect on. I noticed that during this project I had difficulties to conclude. Multiple times I was diverging and even going broader while I should be converging towards a conclusion. This was probably due to the undefined nature of the project from the beginning, the outcome of the project was vague, and I had difficulty in making concrete decisions and moving on. Besides, this was an unusual project compared to the previous projects I have done in the master programme because it started without a specific market in mind. Defining the market and finding the right tools to move on, were therefore difficult to me. For the future, I learned that when I start a project, I have to make sure that the outcome is specific and clear while still having the freedom for my input and choosing my direction.

Chapter 14 |

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