CHALMERS
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Investigating Possible Application Areas & Developing a Marketing Product for the All Cellulose Composite PulpPack™

Master of Science Thesis in the Master Degree Program, Industrial Design Engineering

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Department of Industrial and Material Science
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2017

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ABSTRACT

PulpPack is a new patented method for dry forming cellulose using isostatic high pressure. This study has been conducted with the aim of facilitating the commercialization of PulpPack and to give guidance on possible markets to target. This has been achieved in two steps. First by establishing possible application areas for the method and secondly by developing and manufacturing a marketing product from one of the identified applications. Applications were generated through different ideation approaches and then evaluated in relation to several identified key criteria. The criteria are based on findings from a sustainability analysis, a material benchmarking and a situational analysis of PulpPack. The application chosen to be developed into a marketing product is a passive amplifier for smartphones. The amplifier is designed so that it can function both as a material sample and give away to potential customers. The final design is based on a set of established guidelines relating to PulpPack's manufacturing possibilities and strengths.

Keywords: *PulpPack, biocomposite, all cellulose composite, marketing product, product development process, industrial design, material investigation, paper product, application areas, renewable material, tool development*

PREFACE

The work presented in this thesis was carried out at the department of Industrial and Material Science, at Chalmers University of Technology, together with the company Core Innovation in Gothenburg, Sweden. We would like to start by thanking our examiner and supervisor at Chalmers, Oskar Rexfelt, for valuable input and feedback that have kept us on track throughout the project. Another thanks to everyone at Core Innovation, especially our supervisor Maria Kruse, for believing in us and giving guidance and support along the way. We would also like to thank everyone else who have supported and helped us throughout the project, among others: Alexander Osika at Chalmers Robotförening for teaching us to master the laser cutter, Emil Borglund at eXPerimentverkstaden for helping with the 3D printer and last but not least to our dearest Johan and Gustaf.

Gothenburg May 31, 2017

Matilda Henriksson & Isabel Malone

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INTRODUCTION

This chapter introduces the reader to what the thesis is about and how it is structured. The chapter contains a short background, the aim, objective and scope of the thesis, and a process model over how the work have been conducted.

1 BACKGROUND

The global temperature has, over the past 50 years, increased at the historically fastest rate ever (MacMillan, 2016). The increased global warming, partly caused by the use of fossil fuels, is a threat to our society and the people living in it. One solution that would contribute to lowering global warming is to replace materials made of finite resources with ones made of more sustainable and renewable resources.

The engineering bureau Core Innovation have developed a new method for dry forming cellulose using isostatic high pressure (Core Innovation, 2016). The patented method is called PulpPack and enables manufacturing of 3D formed objects with characteristics equal to certain plastics, see Figure 1.1. The method gives the material enhanced structural properties, thus enabling more fields of applications, compared to regular paper products. One possible domains where PulpPack could be implemented have already been identified, namely as a packaging material.

During 2013, every citizen in the EU generated an average of 156,9 kg of packaging waste (Eurostat, 2016). This fact alone proves the need for replacing packaging solutions that are not possible, or difficult, to recycle or reuse. Moreover, studies show that as people nowadays are more aware of environmental issues, they tend to stay away from materials perceived as being harmful to the environment – especially plastic – and instead go for renewable materials that have a closer association with nature (Inventia, 2016A). So, there are strong incentives both concerning sustainability as well as commercial viability to introduce a material like PulpPack on the market.

There is similar cellulose based materials on the market already. Two of the largest and most relevant opponents to PulpPack are Bagasse, which is a fibrous matter made from remains of sugarcane or sorghum stalks, and Durapulp, a material made from paper pulp mixed with polylactic acid [PLA]. For PulpPack to stand against the competition, a strategy on how to promote and introduce the material to the market need to be worked out, and with that more investigations concerning possible application areas need to be done.

Figure 1.1 – Sample of a product made in PulpPack

2 OBJECTIVE

The master thesis project consists of two distinct phases, where the first phase has the objective of establishing application areas for the material PulpPack. This is to be achieved by exploring the material from different perspectives and mapping out its strengths and weaknesses. The second phase has the objective to develop a physical prototype, made from PulpPack, from one of the identified applications. The prototype should be designed so that it promotes the material and could be used as a marketing tool.

3 AIM

The thesis is conducted on commission by the engineering bureau Core Innovation, as part of their plan for the market introduction of PulpPack. By fulfilling the objectives of finding application areas and developing a prototype the commercialization of the material can be facilitated. By achieving a successful market introduction, less sustainable materials could be replaced by PulpPack, which in turn would have a positive effect on the environment.

4 SCOPE

This project is conducted full time during the total length of the spring semester 2017. The thesis briefly covers the areas of material composition, business strategy and marketing. However, it is first and foremost a project within the areas of design and product development.

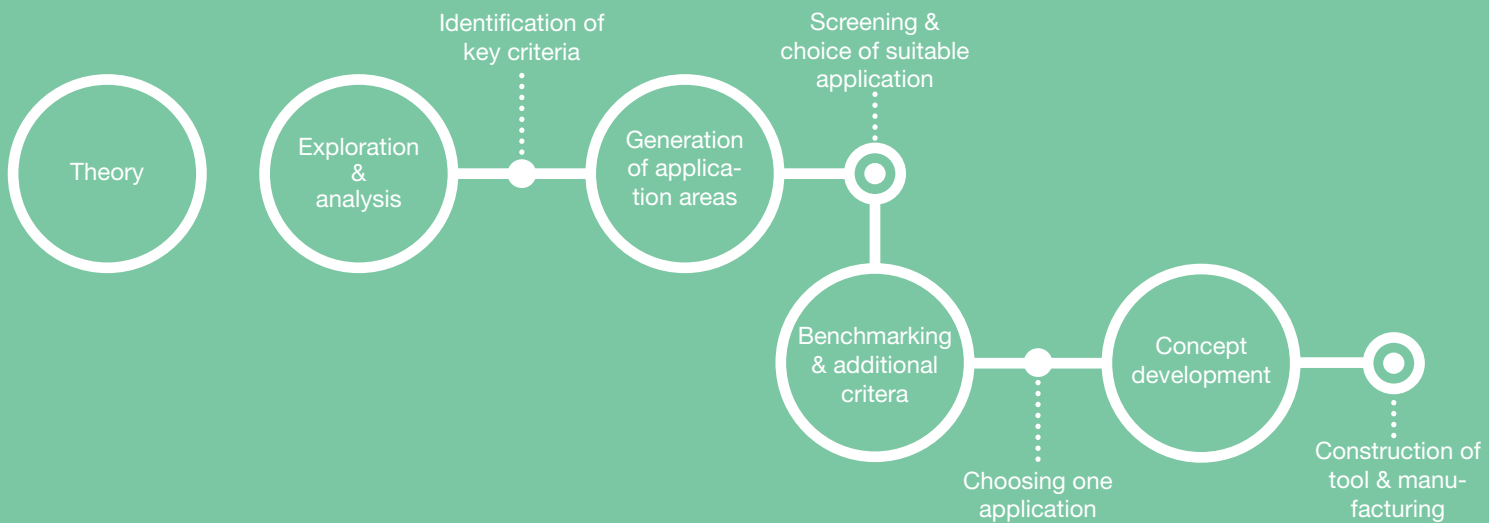
The deliverables of the project will consist of several suitable applications as well as a physical prototype of the chosen application that is to be used as a marketing tool. The prototype that is to be developed should be possible to manufacture in Core Innovations own workshop, which create certain limitations regarding the dimensions and design of the end product.

5 PROCESS & THESIS OUTLINE

The process for this master thesis project is represented by a number of divergent and convergent activities along a timeline with a distinct break between the two main phases, see Figure 5.1 and explanations for each activity on the next page.

The outline of the thesis follows the sequence of activities and phases presented in the process model. However, the chapters of the thesis do not correspond identically to the activities in the process model; some chapters include multiple activities while other chapters cover fractions of activities. The thesis ends with a common discussion and conclusion for the entire project.

Figure 5.1 – Process model



THEORY

- Getting insight about the material and relating subjects to get a sound theoretical foundation to enable knowledge based decisions and stir the rest of the project in the right direction

FIRST PHASE

- **EXPLORATION & ANALYSIS**
  Material comparison, sustainability and situational analysis
- **IDENTIFICATION OF KEY CRITERIA**
  Map out important aspects and benchmark against other materials to define relevant requirements and guidelines
- **GENERATION OF APPLICATION AREAS**
  Ideate using different strategies and tools, and generate as many application areas as possible
- **SCREENING & CHOICE OF SUITABLE APPLICATIONS**
  Evaluate and screen generated applications using previously established criteria

SECOND PHASE

- **BENCHMARKING & ADDITIONAL CRITERIA**
  Establish new conditions that correlates with the aim of creating a marketing tool
- **CHOOSING ONE APPLICATION**
  Evaluate applications and make a knowledge based decision on what application to proceed with
- **CONCEPT DEVELOPMENT**
  Design the chosen application in accordance to the objective and manufacturing possibilities
- **CONSTRUCTION OF TOOL & MANUFACTURING**
  Construction of tool and development of manufacturing method leading up to production of the final prototype

THEORY

This chapter covers the theory necessary to get a deeper understanding of PulpPack. The knowlege retrieved from the information aims at enabling knowledge based decisions further along in the project.

6 WOOD, CELLULOSE & PULP

The cell walls of wood mainly consist of cellulose, hemicellulose and lignin. Cellulose is a polysaccharide that possess excellent mechanical and thermal properties. It is the main constituent of wood and all other plants on land (Huber et al., 2011). Roughly 40–45% of the dry substance of wood is cellulose and it is the most abundant biomass resource on earth (Sjöström, 1993). Approximately $1{,}5x10^{12}$ tonne is produced each year, larger quantities and at a faster rate than anything else on earth (Huber et al., 2011; Innventia, 2016 B).

Cellulose is commonly known as wooden fibers. A more technical name for wooden fibers would be fibrils – the glucose monomers making up the cellulose that form long unbranched strands. The fibrils are bonded together in a matrix of hemicellulose and lignin. Hemicellulose also being a polysaccharide, but with much shorter polymer chains, and lignin being a complex branched polymer that provide strength and rigidity to the cell walls (Danielsson, 2017).

To create paper from wood the process of pulping is used. Meaning to mechanically, or chemically, separate cellulose fibers from the other components of wood creating a slurry called pulp constituting of cellulose fibers and water. Depending on the pulping method, different levels of lignin and hemicellulose are left in the end product which in turn contribute to varying mechanical properties of the pulp (Halonen, 2012).

7 ACC'S & BIOCOMPOSITES

A common definition of a composite is a material consisting of two, or more, distinct materials that when combined form a material with characteristics and properties superior to that of the individual components. A biocomposite is a composite where the reinforcement component is a natural fiber. If narrowing the scope even more, PulpPack can be referred to as an all-cellulose composite [ACC], a monocomponent composite only consisting of "chemically similar or identical cellulosic materials for both matrix and reinforcement" (Huber et al., 2011, p. 1171).

Huber et al. (2011) states in an article about ACC's that there are many benefits of using natural fibers as reinforcement compares to traditional reinforcements like glass or carbon fibers. Most natural fibers have a high specific tensile strength and stiffness, making them a lightweight alternative to mentioned conventional fibers. Moreover, natural fibers are biodegradable, less hazardous to handle and require less energy for processing compared to glass or carbon fibers. However, there are some drawbacks in using natural fibers as reinforcement due to a variation in quality of fibers, posing problems in securing regular and reliable properties in manufacturing.

8 MANUFACTURING OF PULPPACK

PulpPack is a method for dry forming cellulose fiber, using isostatic pressure (Core Innovation, 2016). The raw material consists of processed fluffed pulp, see figure 8.1. Dry forming of pulp, compared to wet forming, could be presumed to be a more energy efficient manufacturing method. This is due to there not being any need for additional processing to dry the products after pressing.

Figure 8.1 – The raw material for making PulpPack is called fluffed pulp and reminds of cardboard

The properties of the final product are dependent on different manufacturing parameters in addition to the composition of the fluffed pulp and how this have been processed. At current time PulpPack has only been tested using one type of fluffed pulp with low content of lignin and hemicellulose. Some studies propose that a higher portion of lignin and/or hemicellulose would give the material even better mechanical properties (Danielsson, 2017). This would also enable the fibril aggregation in the material making it more water resistant. The moisture level of the raw material is also something that have been identified as a parameter affecting the material properties.

PulpPack have similar forming possibilities to other manufacturing techniques such as blow molding, thermoforming and deep drawing. The method allows for complex 3D shapes to be made, without draft angles. This is due to the raw material being very flexible, and thus can be wrapped around corners and double curved surfaces without major difficulties (Danielsson, 2017).

9 PULPPACK AS A MATERIAL

The final product of PulpPack have a plastic-like surface and some mechanical properties similar to common plastics like acrylonitrile butadiene styrene (ABS), polypropylene (PP), polystyrene (PS) and high-density polyethylene (HDPE). PulpPack also has better structural properties than normal paper and is 25% stiffer than wet molded pulp (Core Innovation, 2016).

At present time, the material has only been scholarly investigated in relation to three different manufacturing parameters; pressure, temperature and compression time. These investigations have enabled retrieval of data concerning the following material properties; ultimate tensile strength, Young's modulus, total energy absorption and density. It is established that changing the applied pressure have the largest impact on the material properties (Danielsson, 2017). The highest measured result for all the properties, presented in Table 9.1, was achieved when the manufacturing parameters were set to the maximum limit for the test; 44 MPa applied pressure at 170°C for 300 seconds. However, a shorter cycle time – i.e. compression

time – than 300 seconds would be necessary for a viable big scale manufacturing. On this note, if all parameters stay the same but compression time is instead set to 30 seconds the results in the far right column in Table 9.1 will be achieved.

Research and testing is continuously being done with the objective to improve the properties of PulpPack. The presented data, which is the benchmark for the work in this thesis, refers to PulpPack as a pure cellulose material without any additives or sizing substances – that can affect the material's characteristics.

Table 9.2 is a summary of different characteristics for PulpPack that should be taken into consideration when using the material in product development.

PROPERTY	300 SEC	30 SEC	MEANING
Young's modulus	2,44 GPa	2,3 GPa	stiffness, ability to resist deformation
Ultimate tensile strength	39,9 MPa	29 MPa	ability to withstand loads tending to elongate
Total energy absorption	43,6 µJ	43 µJ	toughness, ability to absorb energy without fracturing
Density	1230 kg/m³	1060 kg/m³	mass per unit of volume

Table 9.1 – Material properties for PulpPack (Danielsson, 2017)

TECHNICAL ASPECTS	DESIGN ASPECTS	ENVIRONMENTAL ASPECTS
• Low cost • Stable • Stiff • Strong in relation to density • No corrosion • Water absorbent	• Allow 3D forms • No draft angles needed • Malleable during manufacturing • Enable double curved surfaces	• Recyclable • Biodegradable • No water consumption during manufacturing • Made from renewable resource • Non toxic

Table 9.2 – Material characteristics

10 RECYCLING IN SWEDEN

Recycling of materials, in particular packaging, is well implemented in Sweden. Every year around 720 000 tonnes of packaging material and magazines are recycled in Sweden (Ftiab, 2017 A). When launching PulpPack as a commercial material it would be beneficial if it could fit into the existing recycling system in Sweden. Swedish law states that the ones producing the waste should make sure that it is collected and taken care of accordingly.

The possibility for close to home recycling only covers packaging materials and is financed by the packaging industry, so that they can use the recycled material for new packages. The definition used for a packaging is a product used for enclosing, protecting or presenting a product. A producer is defined as anyone who professionally produces, imports or distributes a packaging or a product enclosed in a packaging (Ftiab, 2017 B). Packaging that is made of at least 50% paper fiber counts as paper packaging (Göteborgs stad, 2017).

It is possible to recycle a paper fiber 5-7 times, dependent of the requirements of the final product. It is also common to have a mix of recycled fiber and new paper fibers when making paper. Every time a fiber is recycled it gets softer and less durable. This is what is setting the limit for the number of recycling cycles. The energy saving in the use of recycled fiber is 70 % compared to the use of new fiber during manufacture (Ftiab, 2017 C).

FIRST PHASE

/ FINDING APPLICATION AREAS

The first phase presents the work that have been carried out with the objective of establishing suitable application areas for PulpPack. To reach the objective, an explorative material study was conducted followed by different ideation activities, where numerous ideas for possible applications were generated. These ideas were finally evaluated and screened to reveal the most prominent applications.

11 EXPLORATION & KEY CRITERIA

The activities performed in this stage aims at mapping PulpPack in relation to the rest of the world and to identify its strength and weaknesses. The result of the exploration is a list of key criteria for PulpPack. The criteria have the objective of acting as a basis for discussion and evaluation in the upcoming stage of screening and choosing application areas.

11.1 METHOD

MATERIAL COMPARISON

The goal of the material study was to find materials with properties like those of PulpPack. This was done with the objective of further along looking at what those materials are typically used for, and in this way help identify possible application areas where PulpPack can act as a material substitute.

The material database CES Edupack 2016 was used as the main search tool. The software creates material property charts that displays all the materials in so called Ashby charts (Granta design, 2017). The charts plot out two of the entered parameters against each other. The database contains almost 4000 different engineering materials where each material occupies a characteristic field – a bubble. A logarithmic scale is used to fit the entire range of material in one window and each material class has its own color. The software also presents a detailed list with material composition overview, mechanical and physical properties, information regarding process and end of life. The software enables users to delimit the search by other characteristics in addition to mechanical properties – e.g. price, recyclability or biodegradability. This feature was not used in the material comparison of PulpPack to allow a wider search range.

The material properties used in the search settings were the ones that to this date have been able to be determined for PulpPack, namely: Young's modulus, ultimate tensile strength and density. To only show relevant materials an upper and lower level for the different properties were set according to the values presented in Table 9.1.

In addition to CES Edupack 2016 the material database by Material Connexion was used to find similar biocomposites as PulpPack. The result from using Material Connexion's databased was mainly used as inspiration and benchmarking, in contrast to finding specific application areas. The search was performed by browsing through the category naturals and trying to find materials with similar semantics and finishing.

SUSTAINABILITY ANALYSIS

To get an understanding of the material and identify potential problems concerning different sustainability aspects, a sustainability analysis with different approaches was conducted. Since there is no existing full scale production and that the material to this date only have been scholarly investigated concerning material properties, a lot of the data used in the analysis was based on estimations and information about similar materials.

The first step in the sustainability analysis was to look at existing studies on life cycle analyses [LCA] for wet molded pulp and bagasse products. These materials are considered to be the ones most similar to PulpPack that exist on the market today. They are made from the same raw material but the manufacturing method differs. The decision of not conducting a full scale LCA on PulpPack was made based on time constraints and the scope of the thesis.

Instead of a LCA another method was used called a sustainable life cycle assessment [SLCA]. The method is developed by the organization The Natural Step. It is a fast yet comprehensive method to receive knowledge and identify sustainability challenges of a product, its materials and manufacturing processes (The Natural Step, 2017). A SLCA consists of a questionnaire with 140 questions directed to assess the current sustainability strengths and weaknesses of a chosen product system. One could either answer yes, no, don't know or not applicable to the questions. The questionnaire is divided according to five different life cycle stages;

raw material, production, packaging and distribution, usage and end of life. The five lifecycles stages are furthermore covered by the four sustainability principles listed below.

1. *Does the product life cycle contribute to the buildup of substances from the earth's crust? (e.g. metals, minerals, fossil fuels, etc.)*
2. *Does the product life cycle contribute to the accumulation of substances produced by society? (e.g. persistent chemicals, natural compounds produced in volumes that nature cannot handle, etc.)*
3. *Does the product life cycle contribute to physical degradation of nature? (e.g. overfishing, land destruction, erosion, etc.)*
4. *Does the product life cycle contribute to any conditions that undermine people's capacity to meet their needs? (e.g. unsafe working environments, health issues, financial stability, freedom, etc.).*

(The Natural step, 2017)

The product used in the analysis was a disposable container for takeaway food. It was assumed that the raw material for the container was based on Swedish forest and that it was manufactured in Sweden. As previously stated there is no ongoing production of products made from PulpPack today, so assumptions and estimations were made in cases where no existing data was available. The result from the assessment is presented in a color-coded matrix that can be used to identify the root causes of unsustainability across the life cycle, rather than the symptoms.

As a last step in the sustainability analysis of PulpPack two different material tests were conducted to investigate PulpPack's recyclability and biodegradability. The first one was to bury a container, made from PulpPack, in a flowerbed outside Core Innovation's office for a period of 8 weeks. This was done to see how long time it took for the container to decompose. After half of the test period had passed the container were dug up to be examined. The test was consciously

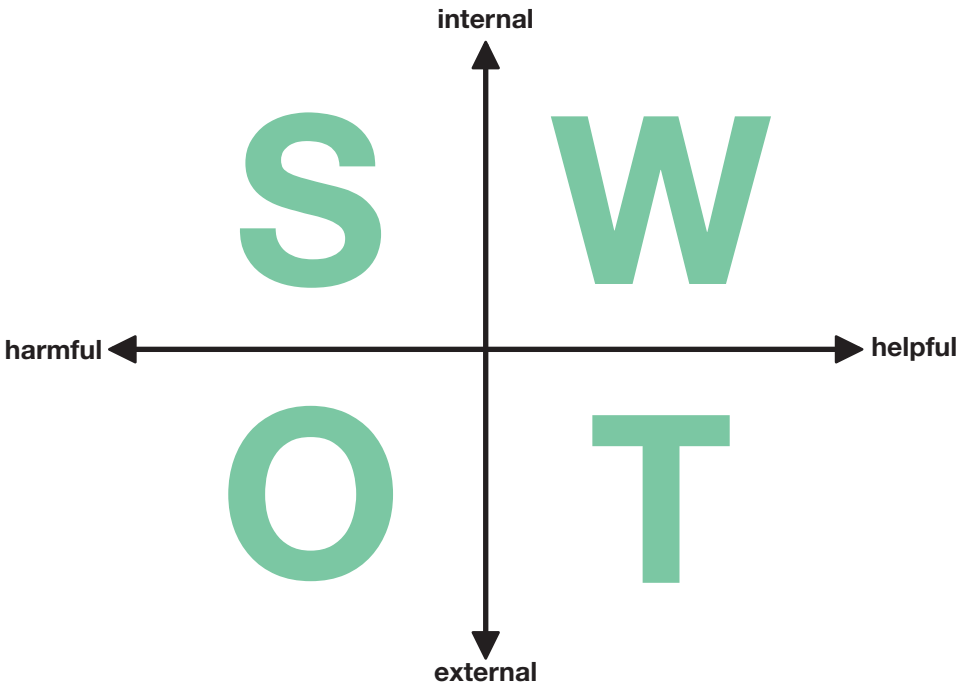
not conducted under optimal conditions. The reason for this being that the test should mimic conditions of the environment in society – where products of PulpPack potently may end up.

The second test was to dissolve the same type of food container to see if it was possible to use the same material to produce a new container. The container was put in a bowl of water where it rested until it dissolved. Afterwards it was put on a plate to dry before it could be tested in the regular manufacturing procedure of the food container. The results from both tests acted as indications rather than as reliable scientific results.

SITUATIONAL ANALYSIS

Despite the lack of having an end product or established manufacturing chain a stakeholder mapping was conducted to identify what parties that are and potentially will be affected by PulpPack being launched on the market. The information from this along with the results from previous analyses, and theory, were

Figure 11.1 – Structure of SWOT-analysis



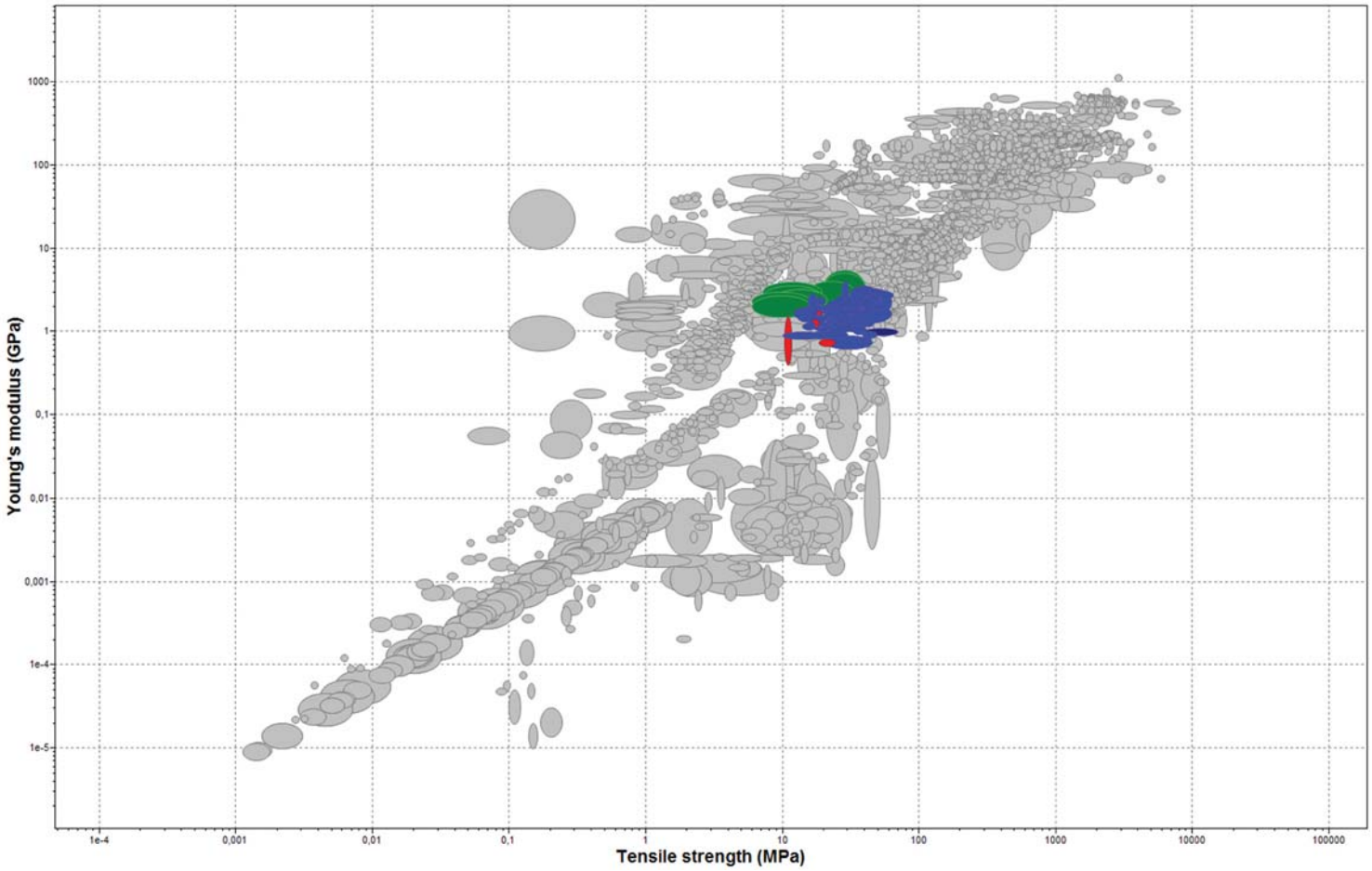


Figure 11.2 – Ashby chart with limits according to the material properties of PulpPack

compiled and acted as a knowledge base to do a SWOT-analysis (standing for strengths, weaknesses, opportunities and threats). The objective of the SWOT was to identify both external and internal factors that can affect PulpPack.

The analysis was carried out as a workshop where a coordinate system was drawn on a large whiteboard creating four quadrants corresponding to the different types of factors; internal strengths and weaknesses (factors that can be derived from within the company or related to the material's own characteristics), external opportunities and threats (factors that can be found in the external environment of society). The labeling of the quadrants structured the analysis with internal and external factors on the Y-axis and helpful and harmful factors on the X-axis, see Figure 11.1. During the workshop, the discussion was open and ideas were added to the board as they came up. People working with PulpPack, other than the authors of the thesis, were invited to join the workshop to prevent that any factors were overlooked.

11.2 RESULT

PULPPACK IN RELATION TO SIMILAR MATERIALS

The material database search using CES Edupack 2016, and the established parameter limits, resulted in 87 materials with similar property values as PulpPack – regarding density, Young's modulus and tensile strength. An Ashby chart was plotted with Young's modulus against tensile strength, where the colored bubbles are materials within the predefined limits for all three parameters, see Figure 11.2. Blue colored bubbles show polymers, green show natural materials and red show composites. All the materials shown in color in the Ashby chart are also listed in Table 11.1 – however, different versions of the same materials are not included in the list. The natural materials found in Material Connexion's database are presented in Table 11.2. These lists will be further examined in the relation to typical application areas for the different materials in the upcoming chapter.

Table 11.1 – Materials from the CES Edupack 2016 database search

● ABS	■ Hardboard	● PMMA
● CA	● MABS	● PMP
● CAB	■ Medium density fiberboard	● PP
● CAP	● PA	● PS
■ Cement bonded particle board	■ Paper	● SB
● EC	● PBT	▲ SBS
● Epoxy resin	● PC	● SMA
■ Fiberboard	● PE	● SMMA
■ Gypsum bonded particleboard	● PE-HD	▲ TPO
	● PLA	● TPU

● = *polymer* ■ = *natural material* ▲ = *composite*

Table 11.2 – Materials from the Material Connexion database

■ Agro Resin	■ Naturess – Kollektion Palmblatt®	■ Palm Fibre Packaging
■ Biodegradable Packaging	■ Molded Paper Pulp	■ PaperFoam
■ Durapulp	■ Mushroom® Material	■ PaperLite®
■ Green Polyethylene	■ MycoFoam™	■ UBPACK
■ Karta-Pack™		

SUSTAINABILITY ASPECTS OF PULPPACK

No hard facts concerning sustainability have to this date been established for PulpPack, but Core Innovation have made calculations indicating that PulpPack would have 60% lower GWP100 (global warming potential) compared to PET (Core Innovation, 2016). A LCA covering different disposable food trays – made from PET, PLA, sugarcane bagasse and wet molded pulp – show that wet molded pulp, followed by sugarcane bagasse, is the preferred material from a sustainability perspective (Rose & Patel, 2011). Both wet molded pulp and sugarcane bagasse are similar to PulpPack but have different manufacturing methods and sources for cellulose.

The examined LCA was commissioned by a bagasse tray producer; but even so, objective data could be deduced. In the LCA the wet molded pulp tray had the lowest impact in the categories of; renewable energy use, eutrophication, photochemical oxidant formation and land use. The only categories that did not show that the pulp tray is the best alternative are; abiotic depletion and acidification. The fact that the LCA is made on certain assumptions, e.g. regarding transportation and chemical compounds of the different trays, should be highlighted and regarded when looking at the results. Moreover, the pulp tray is wet molded, which PulpPack is not. The method of wet molding is assumed to require larger amounts of energy, because of the final process of removing moisture after molding. Dry forming pulp do not include this extra processing step.

Figure 11.3 – The container before being buried, after 4 weeks in the ground and after 8 weeks in the ground

Figure 11.4 – PulpPack container made from reused material

The result from the decomposing test indicates that PulpPack is biodegradable. One source say that paper take about 2–5 months to break down if left in nature (Science Learning Hub, 2008). Another source state that it takes nature 6 weeks to break down a newspaper while it takes cardboard 2 months to biodegrade (Klefbom, 2014). The food container made from PulpPack was buried in early March when it was still some ground frost left, and then dug up 8 weeks later. Figure 11.3 show the container before, during and after the test. The container did not break down completely during the test period but the pictures indicate that most of the degradation occurred over the last 4 weeks when it was warmer weather. Conclusions could be drawn that PulpPack biodegrades at approximately the same rate as paper products of similar thickness.

The recycling test also showed promising results about PulpPack being able to be recycled in manufacturing. Figure 11.4 show a food container made from dissolved and dried PulpPack that have gone through the manufacturing process once before. This proves that the cellulose fibers can be separated after undergoing isostatic pressure. This test does however not prove the quality of the fibers after being recycled, other than the fact that they are able to be used in a second production cycle.

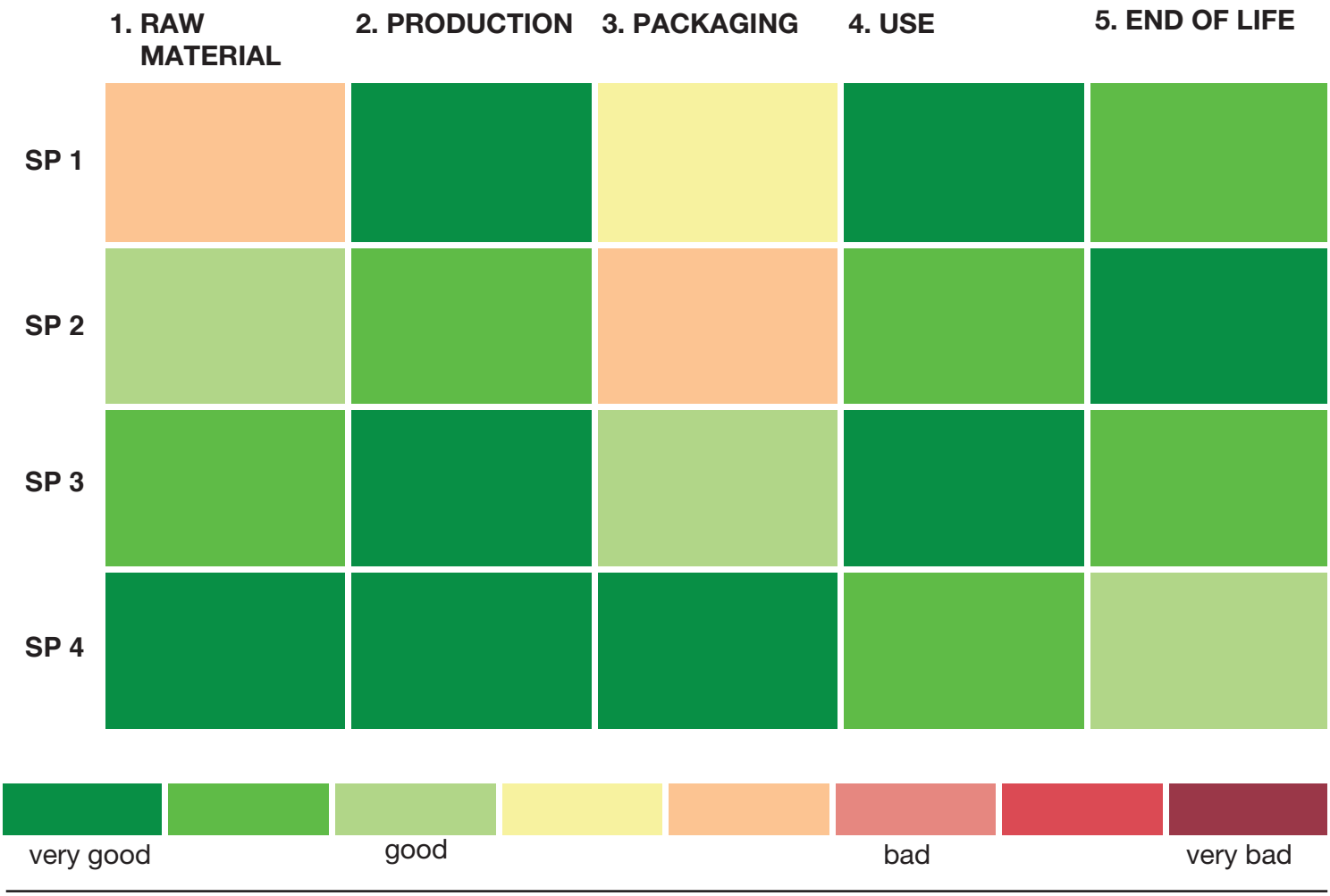


Table 11.3 – SLCA matrix: result of sustainability assessment

The SLCA resulted in the color-coded matrix shown in Table 11.3. The complete questionnaire and answers to all questions can be found in Appendix I. The color of the boxes indicates how satisfying the result is from a sustainability perspective.

'The production stage' is green, indicating it is well performing. This is because the manufacturing process does not create any waste – i.e. all trim offs can be reused in production. Another reason for this is that the production is assumed to be based in Sweden where working conditions are more controlled than in other parts of the world. 'The use stage' is also green because the example product, being a disposable food container, is a passive product. 'The end of life stage' is mainly good based on the materials characteristics of both being recyclable and biodegradable.

The two life cycle stages where PulpPack does not perform as well are during 'the raw material stage' and 'the packaging, distribution & retail stage'. One reason for the inferior result for 'the raw material

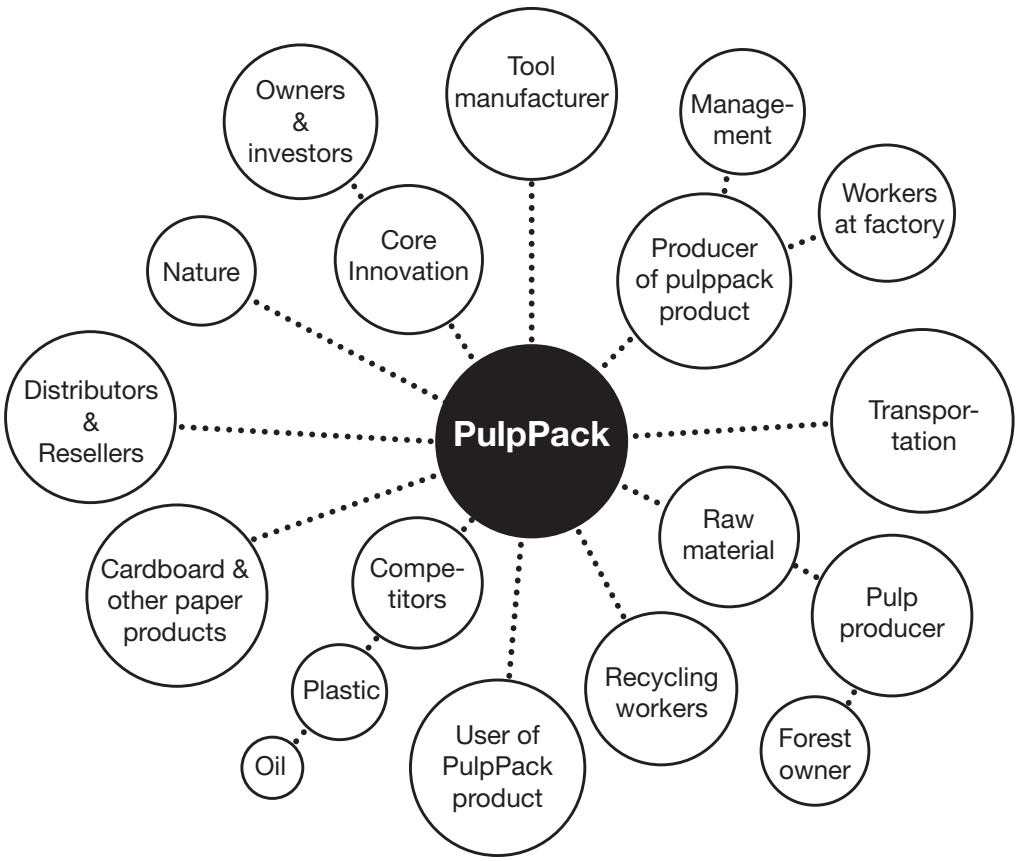
stage' is that there are alternative sources for cellulose fibers that grow in a superior rate to Swedish forest. The reason for the result in 'the packaging, distribution & retail stage' is due to the producer of PulpPack not being able to control the second line and third line packaging used during distribution. Questions concerning this were answered don't know which results in the same score as if these questions had been answered no. Overall, PulpPack can be considered a green material throughout all the different lifecycle stages.

MARKET PLACEMENT OF PULPPACK

Because PulpPack is not yet introduced commercially, Core Innovation still have some control over how the material will be positioned on the market. The stakeholder mapping in Figure 11.5 show actors that potentially will be affected by PulpPack when it is launched.

With the stakeholder mapping in mind together with all other knowledge and insights gained along the project the following result from a SWOT-analysis was achieved, see Table 11.4. The SWOT-analysis resulted in a large amount of aspects to consider in the upcoming work of finding application areas for PulpPack.

Figure 11.5 – Stakeholder mapping of PulpPack



STRENGTHS

- 'Made to measure'-possibility
- Varying experience possibilities (plastic vs. eco)
- Could potentially be made from other raw materials
- Smooth surface finish
- Renewable resource
- Non-toxic
- No additives
- Possibility for upcycling
- Recyclable
- Low density
- Cheap raw material and manufacturing
- Some similar material properties as plastic (could replace)
- Fast manufacturing (possibility for short cycles if higher pressure)
- Water saving manufacturing
- Possibility for complex 3D shapes
- Printable
- No corrosion
- Not dependent on specific raw material, i.e. could be locally produced anywhere in the world
- Biodegradable
- Short lifespan (more suitable for certain applications than other materials)
- Not bound to convention, i.e. developed at small company

WEAKNESSES

- New business area, i.e. expensive and difficult to introduce to market
- Could be perceived as plastic and thus an unsustainable material
- Not able to make transparent
- Not water resistance without coating or other additives
- Short lifespan (more suitable for certain applications than other materials)
- Unchartered area, i.e. no one really knows that much about what happens in the material
- Core Innovation as developer have no previous experience with pulp business
- Underdog developer, i.e. small company not able to make big impact on market
- More difficult to recycle if additives are needed (such as plastic and sizing substances)

OPPORTUNITIES

- Aging population, increased need for disposable goods in e.g. hospitals and care facilities
- Environmental need – consumers are more aware and prefer more natural and non toxic materials than plastics
- Could replace materials in applications where the use phase doesn't correspond to materials lifespan
- Increased need for recycling
- Digitalization leads to a decreased need for printed media, therefor the raw material need to be used in other applications
- A large trend towards outdoor lifestyle and traveling – lightweight and disposable products
- Increasing population, growing middle class increases the need for packaged products
- Large amount of refugees and people living on the road increases the demand for disposable products

THREATS

- There are other, cheaper and faster growing raw material resources (compared to Swedish forest)
- Low oil price
- Digitalization trend and IoT is not easy implemented in PulpPack
- Food grade (laws)
- Competition with similar products that already exist
- Trend toward making physical products digital
- Not desirable to have disposable products

Table 11.4 – Result from SWOT-analysis

PULPPACK CRITERIA

The exploration and analysis of the material resulted in several criteria containing important aspect that should not be overlooked when developing a product in PulpPack. The criteria are a compilation of ideas that have come up along the way, most of them from the SWOT-analysis, but also some relating to the material comparison and sustainability analysis. Each criterion has one, or more, relating questions that could be posed when discussing the development of a potential product.

- **APPROPRIATE LIFESPAN**
  Does the expected lifespan of PulpPack correlate with that of the application area? If not, is this a problem? With what intensity will the application be used, does this matter?
- **FULL POTENTIAL**
  Is the full potential of the material, with all its special characteristics, used? Can the application be made so that it is?
- **VALUE PROPOSITION**
  Does the fact that using PulpPack for the specific application create added value, or could the application might as well be made in any other material?
- **VIABLE MANUFACTURING**
  Would it be possible to manufacture the application in PulpPack in a profitable (and sustainable) way? Compare with conventional manufacturing of the application.
- **CLOSED LOOP**
  Does the application enable a closed loop production? If not possible in present time, would this be possible in the future – i.e. how great is the cradle to cradle potential?
- **STAKEHOLDERS**
  Does all potential stakeholders gain from the application being made in PulpPack? If not, is this a problem?
- **STANDARDS, RULES & REGULATIONS**
  Could laws and regulations cause problems when using PulpPack for the application?

- **FUTURE MARKET**
  Does the application belong to an emerging or existing market? Will the application be relevant in the future and will the same need for the application exist in the future (or will the need/ problem be solved in another way)?

- **INNOVATION LEVEL**
  Does the application enable novelty and potentially new functions to be incorporated in the design?

- **AESTHETICS & EXPERIENCE**
  How are the aesthetics and product experience affected by the application being made in PulpPack? Would the customer trust the material, believing it is strong enough etc.? Or is this not relevant?

- **SOCIETAL IMPACT**
  Does using PulpPack for the application contribute to a better society? Are there any conflicting ethical aspects in using PulpPack for the application?

- **PROFITABILITY**
  Is there a long way between developing to market introduction, i.e. how fast is the ROI for the application? How big is the market for the application?

11.3 REFLECTIONS

- Materials in the database search may have other properties than PulpPack that would disqualify them as a similar material – e.g. almost all polymers found are hydrophobic while PulpPack at this moment is not.

- PulpPack have proven to be a competitor not only to petrochemical materials but also to other natural materials. Both regarding mechanical properties and sustainability aspects.

- To develop a value based product, that will have a chance to compete on the market, one must look at both external and internal factors that relates to the product (or in this case the material for a product).

12 GENERATION OF APPLICATION AREAS

This chapter covers the ideation stage of finding application areas for PulpPack. All the utilized approaches are worked through and the generated ideas are presented in an organized table according to different categories based on functionality and/or market segment.

12.1 METHOD

IDEATION

As a first step in the ideation process of generating applications for PulpPack a method called Search Areas was used. The method is an extension of a SWOT-analysis where the identified internal strengths are set against the external opportunities in a new matrix (Boeijen & Daalhuizen, 2010). The random combinations of opportunities and strengths are meant to act as incentives for unexpected applications. Due to the great number of possible combinations in this case, an initial screening of combinations to focus on was done before ideation started. When investigated further it was not possible to extract application areas from some of the interesting combinations. The approach when using the method was to pick a combination that both authors of the thesis found interesting. Then using the combination as an idea spur when ideating possible applications within the area. This was done repeatedly until all interesting combinations was worked through.

To build on the way of ideating using idea spurs, another brainstorming session was conducted using idea spurs derived from previously established criteria in chapter 11.2.4 and the different characteristics of PulpPack presented in chapter 9. Criteria and characteristics that was included in the search area method was not covered once more.

For each of the materials retrieved in the CES Edupack 2016 database search, conducted in the previous stage, there was an information sheet. The sheets contained information about common applications, among other things. These sheets were worked though and a list of possible applications where PulpPack could replace the existing material were compiled.

The last approach in this ideation stage was to look at existing products, no matter what material they were made from, and see if they could work for PulpPack. This was done in two ways; first by exploring everyday environments and then by going through different product classification lists. Exploring everyday environments meant to actively look at the surroundings with a pair of PulpPack goggles on. Meaning to observe the things one saw and evaluate if it was a possible application area for PulpPack. This process was ongoing throughout the project and identified applications was continuously added to a list. At a couple of different occasions this approach was used in more concrete workshops. Namely when visiting larger

Table 12.1 – Different product classification lists that have been examined

CLASSIFICATION SYSTEM	PURPOSE
• CPC, Cooperative Patent Classification, by UN (www.cooperativepatentclassification.org) • CPA, Classification of Products by Activity, by EU (ec.europa.eu) • SPIN, standard för svensk produktindelning efter näringsgren, by the Swedish government (www.scb.se)	Governmental, with the purpose of being used in trade and economical situations. Includes both services and physical artifacts.
• HS, Harmonized System, by World Customs Organization (http://www.wcoomd.org)	Only physical products. List is used by customs personnel around the world.
• UNSPSC, United Nations Standard Products and Services Code, by the UN (www.unspsc.org)	UN's standard product and services codes, taxonomy of products used in eCommerce.
• GPC, Global Product Classification, by GS1 (www.gs1.org)	Previously known as European Article Numbering [EAN]-Uniform Code Council. For barcoding products.

convenience stores that sell a wide array of different products, like Åhlens City, Claes Ohlsson and Tingstad Företagsbutik. Interesting applications found in the stores were photographed and then added to the list of applications found through other approaches.

There are companies and government agencies that, similarly to the botany work of Carl von Linné, have created systems for classification of consumer products with corresponding subordinate classes, arrangements, relatives and species. Using product classification lists in the generation of application was at first intended to work as a way of structuring all findings. As work progressed and different types of product classification lists were examined, the decision was made to not use any of the lists as a system for segmentation. This decision was made because none of the lists had a structure or purpose that fully correlated with this project. The different lists that were examined, along with their origin and purpose, are presented in Table 12.1.

The last list presented in Table 12.1 is GPC which objective, described by the organization that created it, follows; “classifies products by grouping them into categories based on their essential properties as well as their relationship to other products” (GS1, n.d.). This list was found to be best suited and most in line with the purpose of this project and was used, in contrary to the initial idea, to extract application areas from. Every segment of the list, which can be found in Appendix II, was worked through and possible applications where PulpPack could be used where extracted.

SEGMENTATION

Because none of the product classification lists were fully suited for the task of segmenting PulpPack applications with the objective of facilitating a product development process, a new approach was to create the classification system from scratch. This was done by going through all identified applications and creating an affinity diagram where the applications were sequentially put on a board creating groups based on natural relationships. As a last step in classifying process the different segments where given relevant names.

12.2 RESULT

APPLICATIONS AS A RESULT OF DIFFERENT IDEATION APPROACHES

Through the different ideation approaches a total of 158 applications for PulpPack was generated. The complete list of all applications is presented in Table 12.2.

The Search Area matrix was investigated through the different combinations of opportunities and strengths highlighted in the matrix found in Appendix III. The most notable applications that this method generated was applications relating to societal issues and world trends – like higher environmental awareness and an increased number of refugees on the run. Example of generated applications in these areas are; disposable crutches, camping toilet and baby products like bibs and tableware.

During the brainstorming session where idea spurs was used as a tool to facilitate the ideation, many applications in relation to different market segments were generated. Market segments that generated many ideas were; the hotel and restaurant business, outdoor & camping business and the airline industry. Other idea spurs that were successful in facilitating the ideation was related to characteristics of PulpPack, e.g. the characteristics of being biodegradable and non-toxic.

From the approach of looking at applications for the materials retrieved from the database CES Edupack a lot of divergent applications were found. A complete list of all these applications, and what the conventionally used material for them is, can be found in Appendix IV.

The everyday explorations generated a more divergent set of applications. Many of the identified applications felt obvious candidates for PulpPack, but would have been difficult to come up with if one had not been actively looking for possible applications in the environment. An example of one of these applications is the spool for sewing thread.

The last ideation approach using the product classification list CPS also generated a diverse set of applications. Some of the identified

Table 12.2 – All generated applications in alphabetic order

3D glasses
3D puzzle
analoge amplifier
automatic pet food bowl
baby bib
baby carriage
baby exersisers
baby nest
baby safety products
baby table ware
bag clip
bag for vacuum cleaner
bag in box (for wine)
balcony furniture
beer opener
bike lamp
birdhouse
board game
bobbin
booties for e.g. hospitals
bottle
bowl
box
breadboard
broom
broom handle
bucket
building blocks
bumslider
cabinet carcasses
cable marker
camping toilet
cat clawing board
chewing gum packaging
childrens books with embossed pages
clothes hanger
coaster
coffiee strainer
coffin
cold drink cup
compost bucket
construction helmets
cooking equipment for camping
cooling bag for vaccine
corner protection (baby)
cosmetic packaging
crutch
cup for medicine
cup lid
curtain pole
cutting board
dish brush
dispenser for sprouting
display holder
disposable baking form
disposable barbecue
disposable cameras
disposable cup
disposable cuttlery
disposable hairbrush
disposable headphones for airplanes
disposable plate
disposable shooes
disposable toothbrush
diveder in chocolat or cookie box
doll furniture
dosett
drawer
dustbin for dipers
ear protection
electronic chassi
fire alarm
fire work
flash light
floss container
flowerpot
folding rule
food bowl
freesbee
frosting nozzle
fruit case
garment roller
give away packaging
grass collector for lawn mower
handle for paint roller or brush
happy meal toy
head lamp
helmet
ice scraper
key holder
kids furniture
knee protection
knife case
knitting needle
lamp stand/base
leg protection
litter box
masquerade costumes and masks
matchbox
matches
microphone
miniature fan
mobile phone case
moister absorber
nespresso capsule
odor control for shoes
paint tray
party hat
party light
pen/pencil
pick
picture frame
piniata
plackers
plaster/support/sling
potty
protective shoes
puzzle
rescue kit
safety protection for sockets (baby)
salt & pepper shaker
scientific toy (atomic model, human body etc.)
seasonal ornaments
seed dispenser
shock absorbant structure
shoe last
shovel
shower scraper
shower strainer
sign
spare tire
speaker
spice jar
spool for gift lace
spray bottle
stucco
suitcase
suspensoar
table top
take away packaging
tea light
tea strainer
temporary furniture
tissue despenser
toilet brush
tool box
toy railway set
tray
urn
vuvuzela
wallanchors/plug
waste bin
wee funnel for women
wheelchair components
white board eraser
wine cooler
wine rack
yoghurt container

applications, in contrary to the last approach, felt farfetched and not so obvious – e.g. the application of a compostable grass collector for a lawn mower. Other applications that were found through the product classification list were the paint tray and paint roller/brush handle.

SEGMENTATION OF APPLICATION AREAS

To make the applications in Table 12.2 more foreseeable and useful for future ideation concerning application areas for PulpPack, they were segmented by the categories presented below. A Table of all applications organized by the categories can be found in Appendix V.

- Animals
- Arts & Craft
- Cleaning
- Construction & Tools
- Cooking
- Eating
- Electronics
- Game & Music
- Healthcare
- Holiday & Celebrations
- Home & Interior
- Packaging
- Personal Care
- Safety Equipment
- Sanitary & Hygiene
- Sports

12.3 REFLECTIONS

- Methods like Search Areas and the use of idea spurs during brainstorming sessions was found very helpful when ideating around something without having a well-defined user, function or problem description – i.e. it is difficult to come up with ideas from thin air not having any associations or frames.
- The idea spurs and aspects from the SWOT-analysis had a decisive role in stirring the ideation and creating categories for the segmentation. The outcome of the ideation may have been different if other idea spurs and aspect had been used.

- The identified segments for the applications is not universal in the sense that all types of products correspond to one of the categories. However, the segmentation is made in a way that enables new additions of categories based on either functionality or market segment.

13 SUITABLE APPLICATIONS FOR PULPPACK

This last chapter of the first phase presents the top applications found for PulpPack and covers the evaluation processes conducted in two steps. The presented applications are suggestions of markets to target for the future development of PulpPack.

13.1 METHOD

FIRST LEVEL SCREENING

To enable that as many applications as possible were generated in the previous stage, the ideation had to be allowing and all judgement and skepticism had to be put aside. This resulted in a lot of applications that was not completely elaborated. Because of this and the total amount of different applications generated, a first screening was performed to facilitate the upcoming and more rigorous evaluation.

The first screening was done by color coding all the applications as either green, blue or red. Green being prominent applications to go forth with, blue being good applications but that will not be examined any further in this project, red being bad or not so worked through applications. The decision about each application was taken by having an unstructured discussion, between the two authors of the thesis, based on knowledge gained throughout the project.

EVALUATION MATRIX

After many applications had been weeded out in the first screening, the remaining ones were assessed using an evaluation matrix. The matrix was based on the 12 criteria presented in chapter 11.2.4. To get a more diverse result the criteria were weighted based on

importance. Each criterion got a weighting of either 1 or 2. This was then multiplied with a score between 1 and 10 that each application got for every criterion. The weighting value and scores were decided subjectively based on judgement and previous knowledge relating to the subject.

13.2 RESULT

PRESENTATION OF TOP APPLICATIONS

When the first level screening was completed, a total of 31 applications had been selected as applications to go forth with. These are the applications listed below and the ones illustrated in Figure 13.1. The complete table of all applications and what color they got in the first screening can be found in Appendix VI. All the suggested applications are potential markets to target with the aim of replacing less sustainable material with PulpPack.

- Baby bib
- Bag in box (for wine)
- Bobbin
- Coffee strainer
- Composting bucket
- Construction helmet
- Crutch
- Dispenser for sprouting
- Disposable baking tin
- Disposable headphones
- Floss container
- Garment roller
- Grass collector for lawn mower
- Handle for paint roller or brush
- Litter box (for cats)
- Match box
- Matches
- Paint tray
- Passive amplifier
- Plackers (sort of toothpick)
- Plaster/support/sling
- Potty
- Salt and pepper shakers
- Seed Dispenser
- Serving tray
- Shock absorbent structure
- Sport helmet
- Tea strainer
- Tissue dispenser
- Wall anchor/plug
- Wee funnel for women

Figure 13.1 – A collage of all the applications that passed the first level screening

EVALUATION OF TOP APPLICATIONS

For the assessment using the evaluation matrix, some of the applications presented in the previous chapter were merged as one application. This is because some applications are very similar or that they belonged to the same area of use; so, for this final evaluation the total number of applications was 27. A summary of the criteria used in the evaluation matrix can be seen below.

- APPROPRIATE LIFESPAN
- FULL POTENTIAL
- VALUE PROPOSITION
- VIABLE MANUFACTURING
- RULES & REGULATIONS
- FUTURE MARKET
- SOCIETAL IMPACT
- INNOVATION LEVEL
- AESTHETICS & EXPERIENCE
- PROFITABILITY
- CLOSED LOOP
- STAKEHOLDERS

The complete evaluation matrix with weighting and scores for all the different criteria can be found in Appendix VII. Here follows a list of the ranking for all the application together with the total score they received.

1. Orthopedic cast.....161
2. Shock absorption structure.....160
3. Crutch handel.....157
4. Bobbin (for sewing thread).....154
5. Wee funnel for women.....154
6. Helmet (sport or construction).....152
7. Disposable potty insert.....144
8. Passive amplifier.....143
9. Paint tray.....142
10. Garment roller.....140
11. Bag in box.....139

13.3 REFLECTIONS

- Several of the top ranked applications are both user focused and would have a positive societal impact. These are two aspects that are important for the authors of the thesis and the criteria concerning these aspects had the higher weighting. The ranking would possible look different if someone else, with another background, would have performed the evaluation.
- Not all the applications that was not selected to go forth with in the first level screening are bad choices. As previously mentioned, some of them were just not well elaborated. Recommendation for future work would be to go through the deselected applications once more to see if they still have potential.

SECOND PHASE

/ DEVELOPMENT OF A MARKETING PRODUCT

The second phase presents the work that have been carried out, with the objective of selecting one application and developing a physical prototype that could be used as a marketing tool. The included chapters cover the process of choosing a final concept, the development of this concept and the construction of the tool used to manufacture the prototype.

14 CHOOSING A FINAL CONCEPT

This chapter covers the evaluation and choosing of the final concept. To substantiate the selection, a brief investigation of other marketing products for similar materials was conducted. This in turn helped identify additional evaluation criteria that together with input from Core Innovation supported the selection of which application to go forth with.

14.1 METHOD

BENCHMARKING OF OTHER MARKETING PRODUCTS

Some of the natural materials that were found in the Material Connexion database search, presented in chapter 7, are similar to PulpPack not only because they are biocomposites. They, like PulpPack, are either new to the market or about to enter the market. To see what competition PulpPack might face when entering the market, a brief investigation of some of these materials was conducted. The objective of the investigation was to find out what marketing products the materials have and to see which market segments that have already been covered. Moreover, the result should also work as inspiration and support what criteria might be important when choosing which application to develop as a marketing tool for PulpPack.

EXTENDED EVALUATION MATRIX

To evaluate the identified applications against the new scope, of developing a marketing product, three additional evaluation criteria were added to the evaluation matrix. Two of the new criteria were identified during the benchmarking of other marketing products, namely; how much buzz value does the application have and would the application be suitable as a giveaway. The third criterion had to do with the scope of the entire project; whether the prototype would be able to be manufactured in Core Innovation's own workshop. This criterion was regarded as the most important because it defines the

limitations of the second phase of the project. The new criteria were therefore weighted as shown in Table 14.1 and added to the existing evaluation matrix from chapter 13. All top applications from the first phase were evaluated in relation to each of the new criteria and the scores were added to the total score from the first evaluation matrix.

NEW CRITERIA	WEIGHTING
Buzz value	2
Can be used as giveaway	2
Possibility to make prototype	3

Table 14.1 – Weighting of criteria for marketing product

FINAL EVALUATION

When the first phase of the project was finished and the initial evaluation for the marketing product was done, a halftime presentation of the project was held at Core Innovation's office. During the presentation, all applications that passed the first level screening was presented, but emphasis was given to the six applications that received the highest scores in the extended evaluation matrix. After the presentation, all employees at Core Innovation were invited to take part in a discussion where they gave their input about the different ideas and about which application they thought should be used as a marketing tool.

Before the halftime presentation Core Innovation had decided that they should take part in the international packaging fair Interpack and use it as an opportunity to promote PulpPack. A question that arose during the discussion after the presentation was whether the resulting prototype from the project could be used during the fair and if it would be finished in time. The decision was made that the prototype should be ready in time for the fair and that it should function both as a giveaway and as a material sample.

The news about the fair had a decisive impact on the rest of the project. Not only did it increase the importance of the criterion that the application could be used as a giveaway, it also expedited the

deadline for when the prototype had to be ready. With this in mind together with the input from the discussion with the employees it was down to two applications to choose from. The final choice was made based on the subjective liking of the students together with an evaluation in the form of a pros and cons list. The pros and cons concluded the result from both the evaluation matrix as well as the input from Core Innovation.

14.2 RESULT

MARKETING PRODUCTS FOR MATERIALS SIMILAR TO PULPPACK

The investigation of other marketing products for materials in the same segment as PulpPack showed a varied range of products. Some of these are included in the collage in Figure 14.1. The illustrated marketing products are made from the materials Durapulp, PaperFoam and paper.

Durapulp has many different products ranging from furniture to packaging; the chair Parapu for children, was designed by the Swedish architect Rune Claesson Koivisto with the aim of pushing the boundaries for paper pulp applications (Södra, 2017 A). Claesson Koivisto also designed the lamp w 101, in cooperation with the Swedish lighting company Wästberg (Södra, 2017 B). Durapulp also aims at entering the market as a high-end packaging material. This is shown with their concept Black Box and Tri Shell that exemplifies how fragile items such as glasses and glass bottles could be packaged (Södra, 2017 C; Södra, 2017 D). Another marketing product for Durapulp that demonstrates the biodegradability of the material, is The Seed Pod which was created as a master thesis project by designer Rasmus Malbert (Södra, 2017 E).

Other examples of products made from biocomposites that are new to the market is the champagne cooler from Veuve Clicquot made from PaperFoam and Carlsberg's Green Fiber Bottle for beer. The material for the beer bottle is at present date a secret since the product has not yet launched on the market. Carlsberg has however scheduled a test launch in a pilot market in 2018 (Carlsberg, 2016).

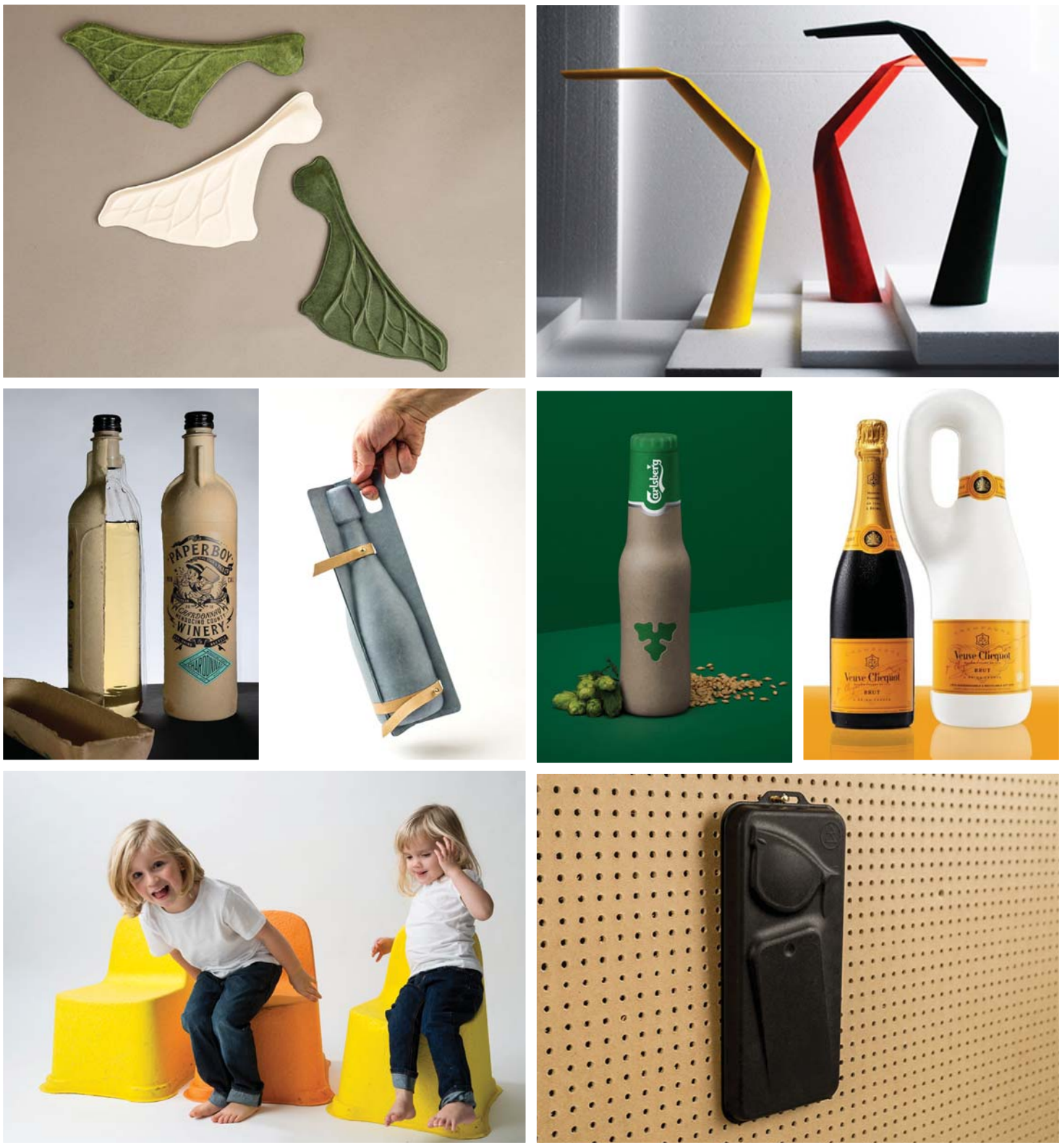


Figure 14.1 – Other marketing products, from top left: Seed Pod (Materialist, 2017 C), w 101 lamp (Södra, 2017 G), Paperboy wine bottle (TinyPic, 2009), Tri Shell (Materialist, 2017 B), Green Fiber bottle (Carlsberg, 2016 B), Champagne Cooler (Marchini, 2015), Parupu (Södra, 2017 F) and Black Box (Materialist, 2017 A).

The final example of a marketing product is the paper wine bottle by Paperboy Wine. The outer layer is made from paper whilst the liquid is contained in a plastic bag. The Paperboy Wine Bottle is currently not available, due to the bottle manufacturers inability to meet a desirable quality (Paperboy Wines, n.d.).

TOP SIX CONCEPTS

The six concepts that received the highest scores in the extended evaluation matrix, together with the total score they received are presented below, followed by a brief description. The complete extended evaluation matrix can be found in Appendix VIII.

1. **The Wee Funnel (222 p)**
   The wee funnel is a product that makes it possible for women to stand up and urinate like men. Products like this already exist but are usually made of plastic and are not disposable. If the product would be made from PulpPack it would be possible to dispose after usage, either in a trash can or in nature – thanks to the biodegradability of the material.

2. **The Structure (209 p)**
   Different types of paper based packaging materials are consumed in large quantities all over the world. Corrugated cardboard consists of three layers of paper – outer liner, flute and inner liner – that are joined with glue. If PulpPack was to be manufactured as a structured sheet it could have the same functionality as corrugated cardboard but with less weight. The structure would be possible to design in various patterns to make it aesthetically suitable for different purposes. The conventional protective structures securing products inside cardboard packaging (usually made from Styrofoam or wet molded pulp) would be redundant if the packaging was made from PulpPack.

3. **The Amplifier (205 p)**
   The amplifier is more specifically the concept of a passive amplifier for smartphones. The application requires that the

soundwaves from the smartphone speaker are directed through something that is horn-shaped. Other than this there are few limitations concerning the overall design, which in turn enables many of PulpPack's form possibilities to be included in the design. The product is small and could work as a giveaway to potential customers.

4. The Bobbin (204 p)

The fourth application is that of a sewing thread spool – a bobbin. The concept could be extended to also include other types of spools or reels used for wrapping string etc. Solely based on the amount of cloths that are produced and sold each year this could be a very profitable market for PulpPack. Most bobbins are today made from plastic and have a longer lifespan than the time for it to serve its purpose. For this reason, PulpPack would be a more sustainable and suitable material.

5. The Support (200 p)

The concept called the support refers to alternatives to conventional orthopedic casts and fixation devices used for broken body parts. Prefabricated shells in PulpPack made in different sizes could be used in development countries, or in war zones, where casting using plaster could be difficult. Other aspects that promotes PulpPack as a suitable substitute are that it is a strong, lightweight, compostable (especially suitable in countries without a functioning system for recycling) and cheap material.

6. The Crutch (195 p)

The crutch is like the previous concept; an aid suitable to use in development countries. The concept is not to make the entire crutch from PulpPack, only the handle. The idea is that the handle should be designed so that it could be mounted to a shaft that could consist of a simple wooden rod or a stick. The same aspects promoting PulpPack as a suitable material for the previous concept also applies for the crutch.

FINAL EVALUATION & CHOICE

During the discussion with the employees at Core Innovation it was decided that the two applications with greatest potential to function as giveaways and material samples at the Interpack fair was the structure and the amplifier. Both options have potential to, depending on their design, effectively display the different characteristics of PulpPack. Both alternatives are also considered neutral – meaning that the product does not take focus from the material properties nor represent a political statement. The strongest arguments for the different concepts are concluded in the pros and cons list in Table 14.2.

Table 14.2 – Pros and cons for the two final concepts

THE AMPLIFIER		THE STRUCTURE	
+	-	+	-
Fun application	A safe choice	Innovative	Not a well elaborated concept
Has another function beside being a material sample	Not innovative in the same sense as the structure	Potential to attract marketing attention if well executed	Concept development process would be longer
Similar manufacturing to existing PulpPack prototypes	Difficult to turn into application that could become profitable	Has a greater commercialization value	Different manufacturing process than existing PulpPack prototypes
Great as a give away			Unsure if it would even work
Customers receiving it would potentially save it and use it			Functions better as a material sample rather than as a give away product

The structure is more on a concept level and needs to be productified to be able to work as a giveaway. The amplifier on the other hand has a clear function and would be rather easy to manufacture because it is more like existing PulpPack prototypes. When the evaluation was completed, and factors like the deadline for the packaging fair was taken into consideration, the final

decision landed on the amplifier. This choice was underpinned by the pros and cons list and supported by Core Innovation.

14.3 REFLECTIONS

- The first of the additional criterion buzz value is difficult to quantify and require a subjective evaluation. The criterion is closely related to what emotions the application evokes. It is hard to pinpoint the exact meaning of it, but at the same time easy to determine that the amplifier would score higher than for example the bobbin.
- When the decision was down to the two final concepts, the fact that the amplifier was a more elaborated idea was a decisive factor for choosing that concept. The idea of the structure is a very wide concept and the development of it could be an entire master thesis project in itself.
- One of the biggest learning outcome from the project would have been that we got the chance to play a vital role in the market launch of PulpPack. The decision to get involved in the Interpack fair had a decisive importance of the development of the project. It gave the project a shorter deadline than before, since the fair was just 6 weeks away when the decision about partaking was made. But at the same time it was energizing and gave the project connection to reality.

15 CONCEPT DEVELOPMENT OF THE AMPLIFIER

The concept development of the amplifier began with an exploration of existing products in terms of shape and design, as well as a brief investigation about fundamental acoustics. This exploration in combination with PulpPack's material properties helped formulate a number of guidelines that the final prototype should fulfill. With this as a foundation an iterative ideation process of sketching, clay modeling and rapid prototyping was conducted. This finally resulted in a complete CAD-model of the concept.

15.1 METHOD

ESTABLISHING DESIGN GUIDELINES

When it was decided that the amplifier was the winning concept, the work of developing the final design of the concept was initiated. An exploration around existing amplifiers was conducted, using the online search engine Google (www.google.com) and the platform Pinterest (www.pinterest.com). Pinterest is a social media platform where users can save and share pictures from different sources on a digital pin board. Images were saved and used as inspiration for the upcoming ideation. Furthermore, to assure that the amplifier would be able to amplify the sound from a smartphone a brief exploration regarding fundamental acoustics and sound was made.

The amplifier should have two different main functions, one as a giveaway displaying PulpPack's different qualities and second as a functioning passive amplifier. To assure that both main functions would be fulfilled, and that the amplifier would be able to manufacture, a set of design guidelines were established. The design guidelines are based on previously established characteristics of PulpPack (see chapter 9), manufacturing possibilities and aspects found in the amplifier and acoustic exploration.

USED IDEATION TOOLS

Once the design guidelines were established the ideation could begin. The inspirational images of existing amplifiers, nice shapes and the guidelines created a foundation for the ideation. Sketching and modelling clay were used in the initial ideation where different designs and expressions were explored. The audio properties were tested by creating mockups from paper and adhesive tape.

Further on in the concept development stage the CAD program Inventor was used to create virtual 3D models that were 3D-printed in PLA. As a complement to the rapid prototyping clay models from industrial plasticine were made. These enabled a more tangible way of assessing smaller adjustments. The process of rapid prototyping and adjusting clay models was iterated until a satisfying result was reached.

Figure 15.1 – Conical horn (Murray, p. 2, 2000 B)

Figure 15.2 – Exponential horn (Murray, p. 3, 2000 B)

15.2 RESULT

DESIGN GUIDELINES

The brief research regarding audio properties gave some guidelines about what to think about when designing a passive amplifier. A horn shape is generally used to increase the acoustic output. Different shapes of the horn, e.g. conical or exponential as illustrated in Figure 15.1 and 15.2, give different audial properties. Conical horns provide no phase or amplitude distortion as it radiates out from the origin, while exponential horns might cause distortion of high frequencies (Murray, 2000).

Figure 15.3 - Inspirational images from top left; iPhone 6 (Apple, 2017), Perk coffee service set (JDXP, n.d.), Tournée Mirror (Something good, n.d.), Black and Copper Amplifier (Variety, 2015), White Alphorn Amplifier (Decorpad, n.d.), Iconico black and white Amplifiers (Serrano, 2013)

This information suggests that a conical shape of the horn is preferred. A selection of the inspirational images found during the exploration of passive amplifiers, loudspeakers and possible designs that would enable a conical shape of the horn are compiled in Figure 15.3.

Aspects found during the research together with PulpPack's characteristics and manufacturing possibilities are reformulated and compiled as design guidelines for the amplifier. These are presented in Table 15.1 and the final concept should fulfill as many of these as possible.

FORM	ADDITIVES	ADDITIONAL
• Advanced 3D form • Double curved surfaces • Made in one piece • Smooth surface finish • Detailed logotype • Deep-drawing • Fit a smartphone • Entails use in upright position • Allow a free way for the audio • Conical shape	• Stiff (starch) • Sharp edges (starch) • Water resistance (sizing agent)	• Biodegradable • Recyclable

Table 15.1 – Design guidelines for the amplifier

SKETCHES & MOCKUPS

Mockups were developed to test the audio properties, as seen in Figure 15.4, showed that a longer horn (150 mm) is experienced to give a better amplification compared to a shorter horn (50 mm). A rotational symmetric horn was also experienced having enhanced audio properties compared to a horn with squared cross-sectional area. Some of the early sketches and mockups that were generated, before the final basic form was decided, can be seen in Figure 15.5 and 15.6.

Figure 15.4 – Mockups for experimenting with audio properties

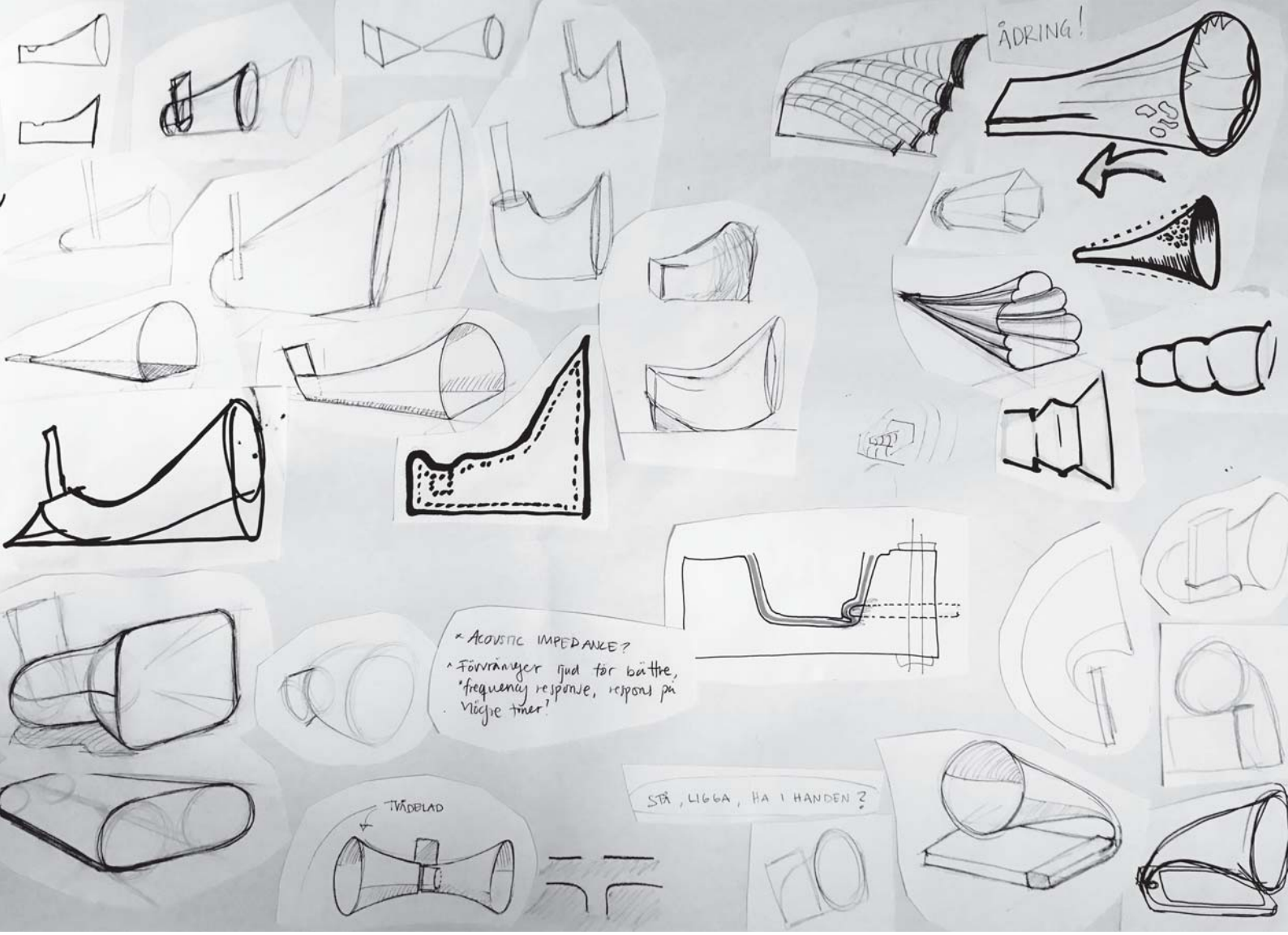


Figure 15.5 – Early sketches

The sketches and early clay models were further developed by the help of 3D modeling in Inventor. The virtual model was 3D printed and new clay models were made to be able to get a better perception regarding shape, size and how the amplifier interacted with the smartphone in terms of shape and balance. A satisfying result was reached after a couple of iterations between clay modeling and rapid prototyping, see Figure 15.7-9.

Figure 15.6 – Early clay models

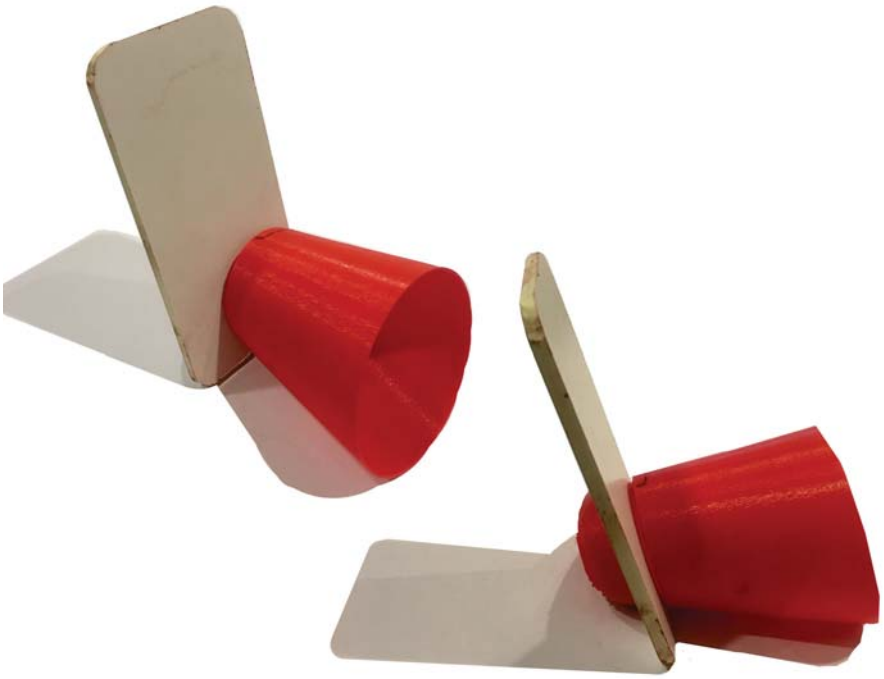


Figure 15.7 – 3D printed version of the virtual model in an early phase

Figure 15.8 – Clay model to test size and balance of smartphone

Figure 15.9 – 3D printed version of virtual model

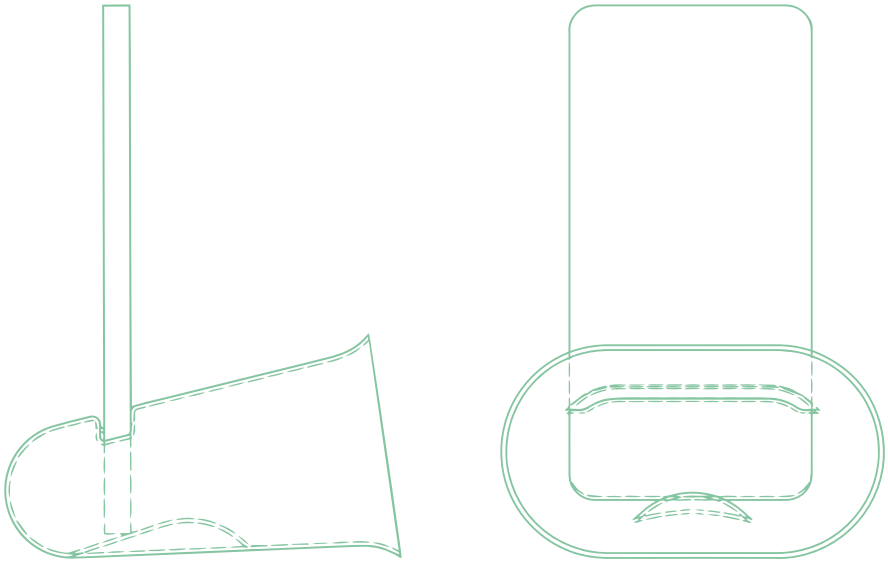
Figure 15.10 – Virtual model of final design

THE FINAL CONCEPT

The final version of the amplifier as a CAD-model can be seen in Figure 15.10. It is estimated that the final design meets 14 of 15 guidelines. The met guidelines are marked with a check in Table 15.2.

Table 15.2 – Fulfillment of guidelines

FORM	ADDITIVES	ADDITIONAL
✓ Advanced 3D form	✓ Stiff (starch)	✓ Biodegradable
✓ Double curved surfaces	✓ Sharp edges (starch)	✓ Recyclable
✓ Made in one piece	– Water resistance (sizing agent)	
✓ Smooth surface finish		
✓ Detailed logotype		
✓ Deep-drawing		
✓ Fit a smartphone		
✓ Entails use in upright position		
✓ Allow a free way for the audio		
✓ Conical shape		



The prototype has an advanced 3D form with double curved surfaces both in the rear part (synclastic) and at the muzzle (anticlastic). The amplifier is made in one piece and designed to have a smooth surface finish with a detailed embossed logotype. The hole where the smartphone should be inserted has deep-drawn edges which both displays the manufacturing possibilities and would hide any unevenly cut edges. The hole for the smartphone is intended for use in upright position and the bulge on the bottom prevents the smartphone from tipping, see Figure 15.11. The bulge also prevents the smartphone from hitting the bottom of the speaker and thereby allow the sound waves to exit the amplifier unhindered, see Figure 15.12.

Figure 15.11 – (left) Section view of the bulge that prevents the smartphone from tipping

Figure 15.12 – (right) The bulge that prevents the smartphone from hitting the bottom

A design related decision had to be made regarding the shape of the amplifier which in turn would affect the tool and the manufacturing of the amplifier. The design of the amplifier could either be made so that the mold is always closed or so that it needs to be opened between each manufacturing cycle. The main benefit of not opening the mold is a short cycle time, but this does however limit the design of the amplifier so that the mold cannot have any protruding parts in a horizontal plane. The opening of the mold between each cycle would entail a considerably longer cycle time since the nuts holding the mold together would need tightening and unloading in each cycle. Despite the extended cycle time the design is based on the principle

that the mold needs to be open each time. The decision about this was made because it opened up for more design possibilities. Design features that are possible due to this is the deep-drawing and the protruding bump at the bottom, that prevents the smartphone from tipping.

15.3 REFLECTIONS

- At first it was difficult to find a suitable design but the process of 3D sketching, using clay models and rapid prototyping was beneficial in the process of constant evaluation and improvement of the design.
- Another benefit with using rapid prototyping is that the PLA-filament is similar to PulpPack in terms of thickness and density. This made it possible to evaluate the stability and balance of the amplifier.
- The fact that the smartphone could be used in upright position when it is placed in the amplifier was a great advantage. Not only is the upright position advantageous from a user perspective but it is also the most challenging position from a solidity and strength perspective, which communicates to an even greater extent that PulpPack is a material to be trusted in, in terms of stability.

16 CONSTRUCTION OF TOOL

The manufacturing method for PulpPack products requires several different tools. This chapter describes the complete process of creating each tool needed to manufacture the amplifier, apart from the industrial hydraulic press that applies the actual pressure. The required tools are; a rigid female mold made of aluminum, a male mold made of an elastomer and an electric heater with a temperature sensor mounted on the aluminum mold.

16.1 METHOD

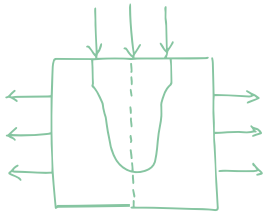
CONSTRUCTION OF THE COMPONENTS OF THE TOOL

In the CAD-program Inventor, the model of the amplifier was pressed down in a rectangular block and then subtracted, leaving behind an amplifier-shaped hole in the block. The block was thereafter splitted into two tool halves to enable CNC-milling in a workshop. Holes for the threaded bars and for guide pins were created. A straight pace in the muzzle part of the tool with an appurtenant punch was created to assure that the hydraulic press would go straight down the aluminum mold.

Once the CAD-model of the mold and the punch was done, several potential manufacturers were contacted. Since there was a short deadline for constructing the tool it was decided to prioritize a short lead time over a low price. A manufacturer close to Gothenburg who was able to produce the mold in five days was chosen.

The chosen manufacturer was consulted and some minor adjustments in the CAD-model needed to be made to be able to be manufactured with a satisfying result. Meanwhile the mold was being manufactured the threaded bars, nuts and plate that are used to assemble the mold, was purchased. The threaded bars were cut to the right length and their edges were chamfered, see Figure 16.1.

Figure 16.1 - Chamfering of threaded bars



M8 strength class 10,9
min. breaking force = 38 1 N

M10 strength class 10.9
min breaking force = 60.3 N

number of bars = 7

M8) 7 * 3.81 = 26,7 tonnes

M10) 7 × 6 03 = 42,2 tonnes

Figure 16.2 - Calculations regarding pressure and durability of bars

To ensure the durability and safety of using of the mold, some computation was made regarding the pressure, see Figure 16.2. The total load from the hydraulic press would in a hypothetical worst-case scenario be directed to the sides of the mold, which means that the threaded bars must bare all the load. The load is divided on seven threaded bars. Each threaded bar with dimension M8 and strength class 10.9 suspends 38,1 N (Nordic Fastening Group AB, 2017). It was found through the computation that the 7 bars with dimension M8 would together suspend 26,7 tonnes. It is earlier stated that the material properties of PulpPack are improved as the pressure is increased. Other products made from PulpPack are pressed with ~40-60 tonnes which corresponds to the amplifier being pressed with 20 tonnes, given that the area of the amplifier is 1/3 as big. To avoid the risk of breaking the mold a decision was made to enlarge the holes, using the milling machine in the workshop of Core Innovation, to be able to fit courser bars.

Once the mold was delivered from the manufacturer some adjustments had to be made. The M8 holes for the threaded bars

Figure 16.3 – (left) Enlarging of holes using the milling machine in the workshop

Figure 16.4 – (right) Chamfering of holes

needed to be enlarged to M10, see Figure 16.3. The new bars with dimension M10 suspends up to 42,2 tonnes and are assumed to be on the safe side enabling usage of the mold without the risk of failing. Since the holes were made with no tolerances, one side of the mold was enlarged to M10 while the other was enlarged to 11 mm. It was a bit of a struggle to make the mold conform but thanks to the usage of the guide pins the mold eventually fitted together in a satisfying manner. Holes for an electrical heating device and temperature sensor as well as a small threaded hole for the ground were also drilled. All the holes were chamfered, see Figure 16.4.

The CAD-model of the amplifier was used as a foundation to create the model for the elastomer device, but given some adjustments. The mantel surface was offsetted inwards to make room for the raw material and the model was complemented with draft angles to enable release of the PulpPack amplifier from the device. The mold for creating the elastomer device was made in Inventor in a similar manner as the aluminum mold, but instead of CNS-milled it was created by rapid prototyping.

TESTING & ADJUSTMENT OF LOGOTYPE

When the mold was assembled, the elastomer device was done, the electrical heater and the temperature sensor were mounted, the complete tool was ready to be tested. The initial test of the mold gave a satisfying result regarding the overall shape. The logotype on the top surface of the amplifier did however not look as expected; the text was too thin. It was decided to send the mold back to the manufacturer and make the letters bolder to make them look more like the logotype. Figure 16.5 shows the result from the first test and the result from the adjusted mold. When a satisfying result was achieved the tool was ready for surface treatment.

SURFACE TREATMENT

Core Innovation have experimented with different types of additives to enhance the material properties, e.g. to increase the stiffness and resistance to moisture. Successful results have been achieved by adding industrial starch to the raw material; making the end product stiffer, with a better surface finish and giving sharper edge when cutting. However, the starch makes the finished product more prone to stick to the edge of the mold which in turn destroys the product. Core Innovation have experimented with different kinds of methods to prevent this from happening. A non-stick surface treatment has proven to be most successful. Once the mold was returned from the surface treatment workshop it was time to start with the production of the amplifiers.

Figure 16.5 – Pictures showing the result from the first test and the result from the adjusted mold

16.2 RESULT

THE FINISHED TOOL

Figure 16.6 – The complete tool

The finished tool consists of four major parts; the surface treated aluminum mold – assembled with seven threaded M10 bars, plates and nuts – the aluminum punch, the elastomer device and the electric heater with a temperature sensor (mounted inside the aluminum mold), see Figure 16.6.

The tool is working together with a hydraulic press and is dimensioned to safely handle 20 tonnes of load. If the load would increase the tool needs to have more threaded bars holding it together and perhaps also increase their diameter. The tool is made for a small serial production where the tool is opened and tightened by hand, using a torx wrench, between each cycle.

16.3 REFLECTIONS

- The construction of the mold had to be done fast due to the short deadline as well as uncertainties regarding the lead time at the tool manufacture and the surface treatment workshop. Because of the quick development time some unnecessary mistakes were made. The calculation of the durability of the mold was made after the mold was sent for manufacturing. This is when the discovery was made about the M8 bars being too weak and that the holes had to be enlarged. The holes for the electric heating device and temperature sensor were completely forgotten when the drawings were sent to the tool manufacturer. These mistakes caused three extra days in the workshop, which could have been avoided.
- The adjustment of the text on the upper surface, to make it more like the logotype costed one extra day. But from a branding perspective it is considered important that the logotype on the prototype would correspond to the website and the printed media.

17 MANUFACTURING OF THE AMPLIFIER

The manufacturing of the amplifiers was made in three steps. The first step was the optimization phase where the process parameters was edited with the aim to find the optimal recipe. The second step was the serial production of the 30 amplifiers that Core Innovation was supposed to bring to the packaging fair Interpack. The third and final step was the finishing process of making the hole for the smartphone and trimming the edge at the muzzle of the speaker.

17.1 METHOD

OPTIMIZATION

In the early stages of the manufacturing process several problems arose. The two main issues were wrinkles by the bulge on the bottom of the amplifier and the emergence of a crack just past the hole for the smartphone, see Figure 17.1. The solution to these problems

Figure 17.1 – Problems with wrinkles and cracks in the early stages of the optimization process

was to adjust the process parameters until a satisfying result was reached. The different process parameters are listed below.

- Tightening momentum – tightening of the aluminum mold [N]
- Weight – the thickness of the raw material [g]
- Temperature – of the mold [°C]
- Pressure – amount of load from the hydraulic press [tonnes]

The manufacturing process was carefully documented using a logbook, which facilitated the identification of successful inputs, making it possible to track backwards when trying to determine which process parameters worked well and which did not. Once all processing parameters were adjusted so that a reproducible high quality of the amplifiers could be achieved the second step of the manufacturing could begin.

SERIAL PRODUCTION

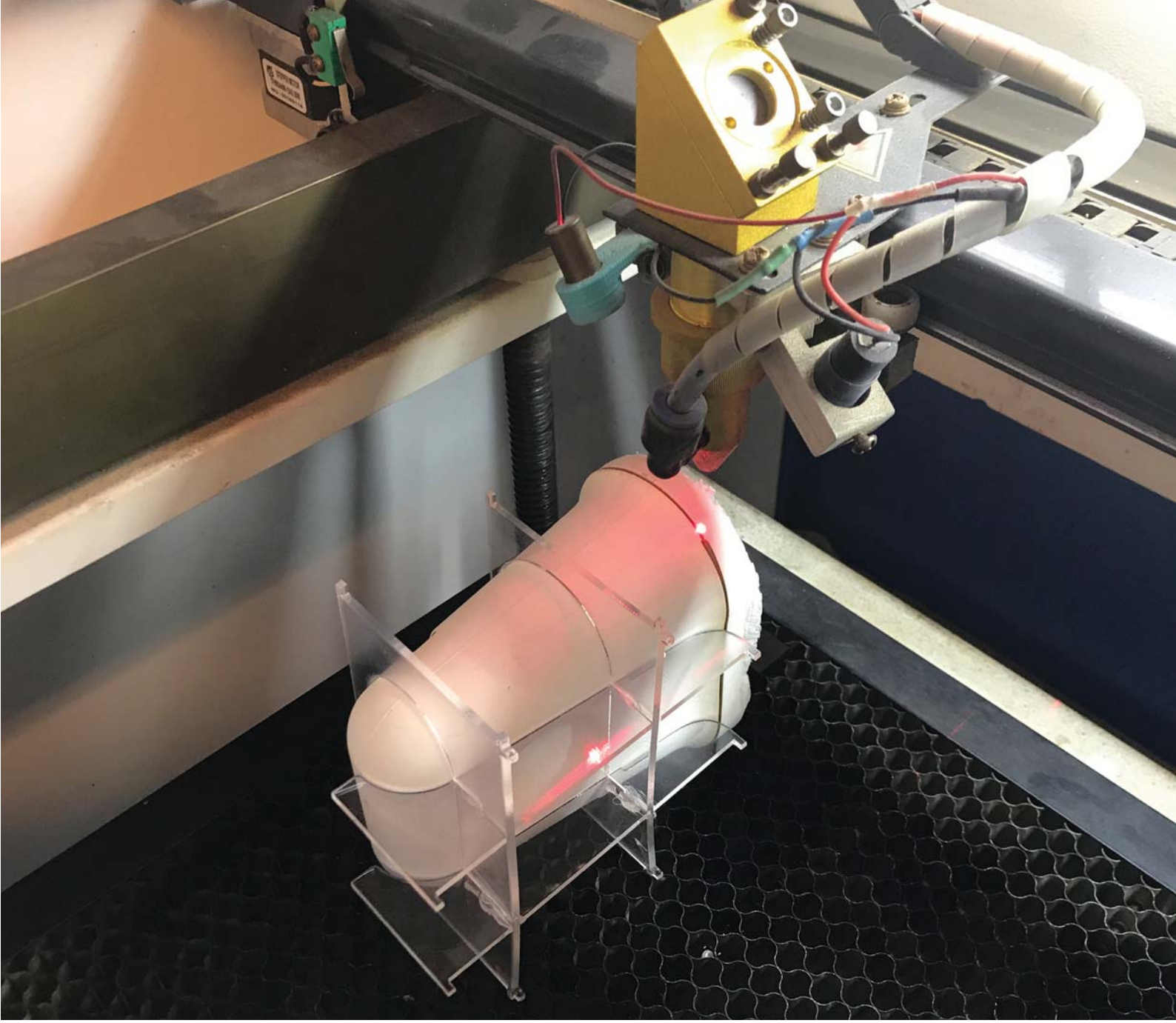
Core Innovation was supposed to bring 30 amplifiers to the packaging fair. The serial production process consisted of two main steps. The first step was to prepare the raw material and the second one was to produce the amplifier's. The production process of the amplifier consists of the five steps below.

1. Prepare raw material
2. Place the raw material in the mold
3. Place the elastomer device and the in the Al punch in the mold
4. Apply pressure using the hydraulic press
5. Open the mold, remove the finished amplifier and close the mold again (done by hand using a torque wrench)

FINISH PROCESSING

The final manufacturing step of the amplifier is the removal of excess material around the muzzle and cutting the hole for the smartphone. A number of methods for creating the hole and trimming the edge was tested; cutting with a pair of scissors, cutting with a razor knife, punching with a chisel and cutting with a band saw. However, none of these methods gave a satisfactory result. leaving the edge uneven or ragged. A sharp edge might seem as an insignificant detail but it had a considerable effect of the perceived overall quality of the prototype.

When exploring other alternative cutting techniques laser cutting was finally found. After some tests laser cutting proved to be a successful method in creating a sharp edge. The laser machine used in this project performed cutting in two dimensions in a horizontal plane, following a given pattern. In this case the pattern consisted of a rectangle with rounded corners for the hole of the smartphone and four separate lines for trimming the edge in four steps; top, bottom, left side, right side. Before each cut was made the laser needed



to be calibrated adjusting the height of the cutting surface and the effect and cutting speed of the laser. To streamline the process and minimize the number of calibrations, a rig was made to ensure the exact position of each amplifier, see Figure 17.2. The design of the rig was made by the help of a section view of the original CAD-model of the amplifier and Adobe Illustrator. The rig was made of acrylic plastic and cut using the laser.

Figure 17.2 – The amplifier mounted in the rig ready to be laser cut

Figure 17.3 –
The final product

17.2 RESULT

THE FINAL PRODUCT

The final product is found in Figure 17.3-17.4.The overall design of the amplifier is sleek and clean and does not take too much focus away from the material. It goes well with the simplistic design of many smartphones on the market.

Figure 17.4 – The final product

The amplifier has a 3D shape with multiple double curved surfaces. The amplifier is made in one piece and has a smooth surface finish and a detailed embossed logotype. The hole on the top for the smartphone is deep-drawn and makes the overall impression of the

product more put together since the cut edges are hidden. The hole for the smartphone is intended for use in upright position but can also be used laying on the side. The overall shape of the amplifier is conical, but it has an exponential flange in the muzzle. This is to connect it to the symbol of an amplifier horn and to make it look lighter by reducing the contact surface to the ground. It could at this stage be verified that the amplifier fulfills 14 of the 15 design guidelines stated in chapter 15.2.1, see Table 17.1.

Table 17.1 – Fulfillment of the design guidelines

FORM	ADDITIVES	ADDITIONAL
✓ Advanced 3D form	✓ Stiff (starch)	✓ Biodegradable
✓ Double curved surfaces	✓ Sharp edges (starch)	✓ Recyclable
✓ Made in one piece	– Water resistance (sizing agent)	
✓ Smooth surface finish		
✓ Detailed logotype		
✓ Deep-drawing		
✓ Fit a smartphone		
✓ Entails use in upright position		
✓ Allow a free way for the audio		
✓ Conical shape		

The amplifier turned out as expected from the CAD model. The material is stiff in the rear end where the radius is small and there is a lot of material. The top surface is wide and flat and therefore weak when compressed. When receiving a material sample at a fair it tempting to examine it by e.g. squeeze it between the thumb and fingers. If the amplifier is squeezed to hard it breaks and becomes soft, the amplifier as it is designed now fits the hand just perfect for this to happen. This would have been possible to avoid through the design, making it less oblong, but it was difficult to predict.

The amplifier was brought to Interpack and handed out to potential customers together with a printed folder and contact information media in a paper bag, see figure 17.5.

17.3 REFLECTIONS

- The production would be able to adopt for larger series production by automating several production steps, above all the opening and closing of the mold.
- In the optimization process of the manufacture parameters it was common that as one issue was solved another occurred. It would have been preferable to isolate one factor at a time to avoid misdirection. This was however not possible due to the long cycle time in combination with a great number of process parameters.

Figure 17.5 – The giveaway kit used during the Interpack fair

DISCUSSION

This chapter covers the common discussion for the entire project. The chapter covers different aspects of the project and ends with the future possibilities of the material.

STRUCTURE & OVERALL METHODOLOGY

The typical product development project origins from a problem discovered by a user. The scope in the beginning of this project problem did not have a problem nor an end user to begin with. Research was made with the purpose of finding similar projects and a methodology that could be followed. Several projects of the same characteristics were found – to find application areas for a known material – but the methodology to do so was not general or particularly structured. Many of the found projects had one single brainstorming session as a foundation when coming up with applications, the brainstorming sessions seemed to have no limitations or frame work, which lead to a variety of ideas that were very random.

Because of the extensive scope of the project – of both finding application areas and develop and manufacture a prototype – the importance of a clear structure and methodology to work by felt well needed. Different tools and approaches were used throughout the project to delimit and structure the activities and work as idea spurs. The initial phase of the project was characterized by an uncritical approach when generating ideas. It is often meaningful to welcome ideas that first might seem out of character and instead be critical in the evaluation of the ideas. Methods like material comparison, sustainability-, situational- and SWOT-analysis and the product classification lists confirmed that the ideation around application areas would not be completely arbitrary.

Having a structure and a working methodically was important in the second phase as well, but in another sense. At this stage of the project there was a lot of ground that had to be covered within tight deadlines. For example, keeping a logbook over the manufacturing was crucial to test different parameters simultaneously and then be able to analyze the result.

The methodology of establish the material characteristics and develop criteria that the product should fulfill might be suitable for other similar projects to create a foundation and framework around the problem.

APPLICATION AREAS

The first phase of the project aimed to find a variety of application areas other than as the name PulpPack implies, a packaging material. The idea of attacking the problem from several directions was to avoid getting a one-dimensional view of the problem. It was found especially helpful to put the material in a context, with a user or with a function when ideating – i.e. it is difficult to come up with ideas from thin air not having any associations or frames.

The number of generated application areas would not have been as many without having any idea spurs during the ideation activities. It was actively considered to be objective and have multiple angles of incidence, but despite the consciousness, it is impossible to get a completely unstained perspective.

The ones performing the study, will have a subjective view and personal set of references that will affect the outcome. Other aspects would most likely have been considered if the ones performing the study had another background than as students within engineering and product development. Because of that background it was also a natural outcome that the focus landed on consumer products rather than to think of components or parts of a solution. The main focus has also been on replacing materials of existing products with PulpPack, but there are countless products that have not yet been invented, perhaps due to lack of a suitable material.

The analysis of the material is not completely universal. There are many approaches of the material that have not been considered. And there are certainly a lot of additional suitable applications of PulpPack beyond the ones stated in this thesis. Some of the suggested applications might be dependent on aspects that have not yet been solved, such as water resistance. The number of possible applications will increase as the material develops and the identified problems with the material is solved.

All the suggested applications from this thesis need to be further investigated both in terms of technical- and juridical aspects. Different regulations regarding e.g. food grade and children's products needs to be closer looked at if chosen to proceed with.

MARKETING PRODUCT

The Interpack fair had a decisive impact over the direction of the project. When it was decided that the prototype made in the project should be ready at the fair it was only six weeks away. The involvement in the fair also contributed to that the prototype should be suitable as a giveaway and a material sample rather than a promotional product. Core innovation emphasized that the product itself should be neutral and not take too much focus from the material. The wee funnel as an example might have a political message to some and therefore draw focus away from the material, this application was therefore considered a bad choice as a giveaway in this context.

The final two options were the passive amplifier and the concept of the structure. The structure concept needed to be productified to work as a promotional product. This meant a longer development time as well as a greater insecurity over if it would work at all. However, the structure concept was more innovative and would have been a great giveaway for the packaging fair. But since it meant a bigger insecurity and because of the tight deadline, it was decided to proceed with the amplifier.

Thanks to the involvement in the market launch of PulpPack at Interpack, pressure was put on the project. The entire development of the tool needed to be carefully planned and the lead time for the different manufacturing steps needed to be considered. Many activities were done simultaneously to be able to make it. But of course, everything did not go according to the plan; the holes in the aluminum mold was too small and had to be enlarged, the hole for the heater and the temperature sensor was forgotten and had to be drilled and the text on the mold did not turn out as expected and needed to be remade. Since the prototype needed to be done on time for the fair, these problems needed to be taken care of accordingly. This nerve and pressure of being involved in a sharp is an important learning outcome of the project. Another learning outcome from this stage is from the responsibility of finding suppliers and managing the purchasing and negotiation of the tools and surface treatment.

It was also thanks to the Interpack fair that generous support from Core Innovation was given in terms of encouragement, a budget for the tool and assistance and guidance in the workshop. Without their help, it would not have been possible to achieve this result.

SUSTAINABILITY & ETHICS

To investigate sustainability aspects in relation to PulpPack was not just important for the product development process, but also because it is a distinguishing aspect for PulpPack as a brand. Because there is not yet a real production for any PulpPack end products, it was difficult to perform a proper life cycle assessment for the material. A simpler version (an SLCA) was instead performed, but even this was based on a lot of assumptions. Furthermore, this study indicates that it would be possible to fit PulpPack into current recycle systems. But further investigation needs to be made when it is stated what kind of product it will be (packaging material or not) and what kind of additives it will have. The tests that were performed in relation to the biodegradability and recyclability of the material were performed in a way so that the results can only be used as hints and indications. Because of this it is important that new investigations concerning sustainability and recycling are performed when more data is established for the material and when there is a full-scale production of any PulpPack product.

Several of the suggested applications where PulpPack can be used as a substitute material are disposable products that are conventionally made from plastics. Some would argue that this is not a defensible argument for saving the environment; to replace disposable products with other disposable products, rather than to focus on changing behavior into not using disposable products at all. It is also conceivable to say that this is to make the most out of the situation and a step in the right direction. On that note, it is believed that it would be difficult to completely change consumption in a trice, especially as consumption trends move more toward packaged goods and take away articles. By keeping disposable products but make them from renewable materials could have a larger positive impact on the environment because the majority of users would be affected. Making a disposable product into something with a longer lifespan would tend to a smaller group of users.

TOOLING AND MANUFACTURING

The tool and the manufacturing process for the amplifier were developed according to the prevailing conditions of Core Innovation's workshop. Neither the tool nor the manufacturing process would work in a large-scale production as they are currently designed. The rigid component of the tool is made from aluminum, which is a soft metal, and could only handle a limited number of cycles compared to if was made from steel. Moreover, the fact that the tool needs to be manually opened for every produced amplifier both prolongs the cycle time and could contribute to wearing out the tool if not done correctly. With this said, the developed tool together with the established manufacturing process does however give a satisfying end result in relation to the stated objective.

Different methods for trimming the edges and creating the hole for the smartphone was tested. The method of using laser cutting gave the most satisfying end result. The edges got a bit burned but this did not disturb the overall appearance of the product. Nevertheless, this method would also need to be further developed for any future production of PulpPack products sins it required a lot of manual work. It is also possible that the method of using a chisel to punch out holes and to trim edges could work as well if a customized tool was developed.

THE FUTURE OF PULPPACK

As of now, there are still many questions about PulpPack that needs to be investigated and solved for it to truly outcompete plastics and other less sustainable materials. Some questions that have not yet been answered are; what happens inside the material on a molecular level during manufacturing, what is the effect is of using different additives and how to solve the problem of making end products water resistant? As this point only one type of raw material (fluffed pulp) have been tested, as stated in chapter 8. Other types of fluffed pulp with another portion of lignin and/or hemicellulose will give the material other mechanical properties. The difference between the usage of different raw material needs also to be investigated on a molecular level.

Even though the answers for these questions are unknown at present time, this study have been able to identify several application areas for PulpPack that could be realizable in the near future. It is however believed that more applications can be established when the above questions are answered, and that it would be easier to do it the other way around compared to how it was done in this study. That is, it would be easier to match an application with a suitable material rather than trying to find applications for a material. It is believed that when doing it the other way around would increase the probability that the full potential of PulpPack would be utilized in an application.

On these accounts, the recommended next step for PulpPack would be to first find answer to all currently unanswered questions and then get PulpPack known as an established renewable material – so that it is easy to find for designers and product developers. This would create a market pull rather than a market push.

CONCLUSION

This section is a breif summary of key insights and conclusions relating to the entire project.

This study set out to facilitate the market introduction of the cellulose based material and manufacturing method PulpPack. This have been done in two steps. First by identification of a wider range of possible application areas compared to just packaging – which had been established before the study. Secondly by the development and manufacturing of a passive amplifier, made from PulpPack, that promotes the strengths and opportunities of the material and thus can be used as a marketing tool.

The application areas were possible to establish by first mapping out PulpPack's material characteristics and then by establishing key criteria that were used in evaluating the suitability of the generated applications. The most important competitive aspects of PulpPack that were identified are that the material is biodegradable, renewable, cheap and that it has a more suitable lifespan for disposable products compared to plastics.

Drawbacks of the material are the sensibility to wear and the low resistance to moisture, which hinders PulpPack in being a ideal opponent to plastic. However, as the research about PulpPack progresses these hinders might be possible to overcome. As the world develops it is necessary to find ways to free us from the need for non-renewable resources and thus we cannot afford not giving PulpPack a chance.

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APPENDICES

APPENDIX I

– SLCA QUESTIONNAIRE WITH ANSWERS

Standardised SLCA Questionnaire (version 1.0, February 3rd 2012)

This document contains a Standardised Questionnaire for Sustainability Life Cycle Assessment (SLCA) – a product sustainability assessment methodology which helps to create a strategic overview of social and ecological sustainability impacts at a product level. The analysis and synthesis of the answers to the questionnaire can be presented in a qualitative colour-coded matrix that communicates sustainability impacts and life cycle thinking to non-experts. The insights from the analysis allow for identifying development pathways towards sustainability.

The SLCA process

The questionnaire is intended to be used as a part of a ten step process, following the ISO standards for Life Cycle Assessment (ISO 1404X) and the strategic planning methodology promoted by The Natural Step (the Framework for Strategic Sustainable Development). The questionnaire is used for '*Step 5 – Sustainability Assessment*'. Read more about the SLCA methology at *www.thenaturalstep.org/slca*

The following resources are a part of the SLCA tool kit provided through The Natural Step's SLCA training: this Standardised SLCA Questionnaire, an SLCA Process Guide, a Glossary of key terms, and an excel file for quick analysis of assessment outcomes.

Using this tool requires:

- Strong knowledge of the Sustainability Principles and the science behind them (read more about the sustainability Principles here: *www.thenaturalstep.org/en/our-approach*
- A good understanding of the methodology of '*backcasting from sustainability principles*'.
- Awareness of the rationale behind this tool, its intended purpose, strengths and limitations. Learn more at *www.thenaturalstep.org*
- Following the ten step SLCA process.
- Following the 'terms of use' oulined below.

About the Standardised Questionnaire:

- There are 140 questions in total, carefully directed to assess the current sustainability strength's and weaknesses of a chosen product system.
- The questions are divided across five life cycle stages with seven questions for each of the four Sustainability Principles and life cycle stage. On an overarching level, the questions are there to identify root causes of unsustainability across the life cycle, rather than identifying unsustainability symptoms. This means that the questions help assess if the product life cycle contributes to...
  - ...systematic build-up of substances from the earth's crust in nature; [relating to Sustainability Principle 1]
  - ...systematic build-up of substances produced by society in nature; [relating to Sustainability Principle 2]
  - ...systematic physical degradation of nature; [relating to Sustainability Principle 3]
  - ...any conditions that undermine people's capacity to meet their basic human needs; [relating to Sustainability Principle 4]
- The questions are designed to be answered in a 'yes', 'no', 'don't know' or 'not applicable' manner.
- The questions are divided into 'impact' and 'progress' questions:
  - Impact questions help identify where there currently are violations of the four sustainability principles across the life cycle of the product.
  - Progress questions help assess the current capacity to make strategic progress towards full alignment with the sustainability principles. Note that in this questionnaire the progress questions are formulated from the perspective of the producer.

How and when to use the Standardised Questionnaire:

- Answering the questionnaire is Step 5 of the SLCA process – it can not be effectively used on its own and should be used as part of a facilitated process involving all 10 steps.
- The process of answering the questionnaire can highlight important issues and it is the quality of the dialogue and capturing of conclusions that are important. There is a field for notes and comments which allows for capturing of important notes for the analysis and synthesis.
- The questionnnaire is best answered by a cross-functional team where the combined knowledge can build a shared picture. Knowledge gaps are important to highlight.
- Answering the questionnaire will not in itself point out which sustainability impact areas to prioritise in terms of moving forward as quickly and successfully as possible towards a sustainable product system. It will only help highlight the gap to sustainability. Coming up with a strategic road map and action plan for how to bridge the gap is the result of the continuation of the strategic planning process that follows (Step 6-10).
- Accompanying this questionnaire is an excel file that gives a means for tallying of answers and communication of the restuls.
- Since this is a standardised questionnaire, it is not fit for all purposes. Some tailoring might need to be done if the product system under study does not fit the scope described below.

Terms of use

In the interest of promoting the further development of this questionnaire and Sustainability Life Cycle Assessment methodology, the Standardised SLCA Questionnaire is shared under the following licensing terms.

You are free:

- To Create: To produce works from the Standardised SLCA Questionnaire, i.e. to use the questionnaire to carry through SLCA assessments on products.
- To Share: To copy, distribute and use this document, including the Standardised SLCA Questionnaire, for the purposes of conducting a product sustainability assessment, i.e. you're allowed to distribute the Standardised SLCA Questionnaire to assessment team members.
- To Adapt: To modify, transform,build upon and re-utilise parts of the Standardised SLCA Questionnaire.

As long as you:

Attribute:

- You must attribute any public use of the Standardised SLCA Questionnaire (i.e. when you use share it/use it with others than You) with the following disclaimer: "This Standardised SLCA Questionnaire is part of The Natural Step's generic tool for Sustainability Life Cycle Assessment. For more information visit *www.thenaturalstep.org/slca*
- You must attribute adapted versions of the Standardised SLCA Questionnaire with the following disclaimer: "This is an adapted tool [or questionnaire] for Sustainability Life Cycle Assessment – a method promoted by the international sustainability NGO The Natural Step (*www.thenaturalstep.org*)." Adaptations of the Standardised SLCA Questionnaire must not be labelled with The Natural Step's logo.
- You must make clear to others the license of the Standardised SLCA Questionnaire and keep intact any notices on the original document.
- Note: Works produced with the help of the Standardised SLCA Questionnaire, i.e. SLCA assessments carried through with the help of the questionnaire, do not have to be shared publicly and must not be attributed to The Natural Step unless they have been carried through by an employee, associate or affiliate organisation of The Natural Step.

Share-Alike:

- If you publicly use or redistribute the Standardised SLCA Questionnaire, or an adapted version of it, you must offer it under the same license as this one.

Feed-back:

- → You are asked to share with The Natural Step any adapted versions of the SLCA that you may produce, as well as insights gained and outcomes from applying the SLCA methodology. This is to help further develop and promote the methodology.

The Standardised SLCA Questionnaire will be updated on an ongoing basis as it is tested and further refined. To stay in touch and ensure that you have the most up to date version, please join the SLCA Development Community. Visit this website for further information: *www.thenaturalstep.org/slca*

Disclaimer

This Standardised SLCA Questionnaire is shared by The Natural Step as a means of promoting a strategic sustainable development. It is shared as is and The Natural Step is not responsible for how it is used or the conclusions drawn by its use.

The scope of the Standardised SLCA Questionnaire

The Standardised SLCA Questionnaire is based on using the following system boundaries, as definied in Step 3 of the SLCA process. If the product system that you are focussing on does not fit these boundaries, it is likely that the questionnaire will miss some impact areas.

1. Raw materials. This covers the extraction of resources, their processing/synthesis and transport to the gates of production where the resources will be used as raw materials to produce the product. This includes material inputs, energy inputs, stakeholders, waste and associated emissions. Excluded are: the production, maintenance and dismantling of extraction and processing plant/machinery; and packaging materials for raw material transportation.

2. Production. This covers from the arrival of the raw materials at the factory gate to finished product ready to package. This includes material inputs (processing materials/substances), energy inputs, stakeholders, emissions and waste, but excludes the production, maintenance and dismantling of production plant/machinery. Transports of personnel is also excluded.

3. Packaging, distribution and retail. This covers the extraction and production of primary, secondary and tertiary packaging; warehousing; and transport and distribution to retail customers and final users. Including key material and energy inputs, but excluding details around the distribution network, such as the building, maintenance and dismantling of roads, vehicles and buildings.

4. Use and maintenance. This covers the installation, use and maintenance of the product until the product no longer functions and is removed/discarded. Including material and energy inputs.

5. Product fate /End of Life. This covers the recovery, transports, processing and final fate (reuse, recycling, landfilling, treatment, etc) of the product after its use has ended. Indluding material and energy inputs, but excluding the production, maintenance and dismantling of vehicles and plant/machinery used throughout the life cycle stage.

Standardised SLCA questionnaire

Enter project information below

Project / product name: Click here to enter text.	**Team members:** Click here to enter text.
Product description: Click here to enter text.	**Date / version:** Click here to enter text.
Responsible for assessment coordination: Click here to enter text.	**Notes:** Click here to enter text.

Raw materials

Number	Question	Answer	Notes / Comments
	Sustainability principle 1 – In a sustainable society, nature is not subject to systematically increasing concentrations of substances from the earth's crust.	Yes, No, Don't know, Not applicable (N/A)	
	Impact questions		
1.1.1	Are the raw materials free from substances from the earth's crust that are scarce in nature*? (e.g. Cu, Ag, Sn, Cd, Hg, etc)	*Yes*	...
1.1.2	Are the raw materials sourced in ways that avoid release of substances from the earth's crust? (i.e. during virigin extraction, sourcing of natural resources and/or recycled or reused materials etc.).	*No*	OSÄKER PÅ FRÅGA
1.1.3	Are all raw materials extracted, processed and transported using fossil-free energy sources?	*No*	...
	Progress questions		

1.1.4	Are there targets and are actions being taken to to phase out* use of raw materials from the earth's crust that are scarce in nature? (i.e. through product development, R&D, etc)	*Yes*	...
1.1.5	Are there targets and are actions being taken to achieve zero waste/emissions* (of materials originating from the earth's crust) in the raw materials supply chain?	*Yes*	...
1.1.6	Are there clear purchasing guidelines for all raw material suppliers relating to sustainable use and management of substances from the earth's crust? (e.g. including SP1 resource use, processing, energy use, waste, product development, etc)	*Don't know*	...
1.1.7	Are there regular audits* of raw material suppliers regarding their sustainable development practices relating to the use and management of substances from the earth's crust that are scarce in nature?	*Don't know*	...
	Sustainability principle 2– In a sustainable society, nature is not subject to systematically increasing concentrations of substances produced by society.	Yes, No, Don't know, Not applicable	
	Impact questions		
1.2.1.	Are the raw materials free from substances produced by society that risk accumulating in nature? e.g. persistent or bioaccumulative substances, and those released to nature at higher flow rates than nature's assimilative capacity.	*Yes*	...
1.2.2	Are the raw materials sourced in ways that avoid release of substances produced by society that risk accumulating in nature during sourcing? (i.e. based on renewable raw materials and/or recycled or reused substances)	*Yes*	OSÄKER PÅ FRÅGA, tänker ej att det gäller CO2.
1.2.3	Are all raw materials extracted, processed and transported using energy sources that do not risk release of substances produced by society that risk accumulating in nature?	*No*	...

	Progress questions		
1.2.4	Are there targets and are actions being taken to to phase out* raw material substances produced by society that risk accumulating in nature? (i.e. through product development, R&D, etc)	*Yes*	...
1.2.5	Are there targets and are actions being taken to achieve zero waste/emissions* (of substances produced by society) in the raw materials supply chain?	*Don't know*	...
1.2.6.	Are there clear purchasing guidelines for all raw material suppliers relating to sustainable use and management of substances produced by society? (e.g. including resource use, processing, energy use, waste, product development, etc)	*Yes*	...
1.2.7	Are there regular audits of raw material suppliers, regarding their sustainable development practices relating to the use and management of substances produced by society that risk accumulating in nature?	*Yes*	...
	Sustainability principle 3 – In a sustainable society, nature is not subject to systematically increasing physical degradation.	Yes, No, Don't know, Not applicable	
	Impact questions		
1.3.1	Are the raw materials free from rare, threatened, endangered or structurally important organisms or species? (e.g. rare corals, kelp, shark fins, rhinoceros horns, top predators, etc)	*Yes*	...
1.3.2	Is systematic physical degradation of nature avoided during the extraction, processing and transportation of the raw materials? (e.g. through heating water, exessive water extraction, land conversion, habitat destruction, overfishing, bi-catch, deforestation, etc)	*Yes*	...

1.3.3	Are all raw materials extracted, processed and transported using energy sources that do not contribute to systematic degradation of nature by physical means?	*No*	...
	Progress questions		
1.3.4	Are there targets and are actions being taken to ensure that rare, threatened, endagered or structurally important organisms or species are not used as raw materials? (i.e. through sourcing, auditing, material selection in product development, etc)	*Yes*	...
1.3.5	Are there targets and are actions being taken to eliminate systematic physical degradation of nature during the extraction, processing and transportation of the raw materials? (e.g. through low impact extraction / harvesting techniques, use of certification systems, avoidance of landfilling, route selection and modes of transport).	*Yes*	...
1.3.6	Are there clear purchasing guidelines for all raw material suppliers relating to sustainable physical use of natural systems? (e.g. including natural resource use, processing, energy use, waste, etc)	*Yes*	...
1.3.7	Are there regular audits of raw material suppliers, regarding their sustainable development practices relating to the physical use and management of natural systems?	*Yes*	...
	Sustainability principle 4 – In a sustainable society, people are not subject to conditions that systematically undermine their capacity to meet their needs.	Yes, No, Don't know, Not applicable	
	Impact questions		
1.4.1	Are the raw materials free from substances whose use risks undermining people's (current and future generations) capacity to meet their needs? (e.g. inherently unsafe substances, wasteful use given other societal needs, etc)	*Yes*	...

1.4.2	Are the raw materials sourced fairly and in ways that support the long term wellbeing local communities?	*Yes*	...
1.4.3	Do working conditions in the supply of raw materials avoid violating human needs in a systematic way?	*Yes*	...
	Progress questions		
1.4.4	Are there targets and are actions being taken to ensure that there are no conditions in the raw materials supply chain that systematically hinder people from fullfilling their basic human needs?	*Yes*	...
1.4.5	Are there targets and are actions being taken to ensure that materials are sourced fairly and that suppliers support the long term wellbeing of the local communities in which they operate?	*Yes*	...
1.4.6	Is a Code of Conduct integrated into all raw material purchasing decisions to help meet SP4? (e.g. health and safety policies, ethical sourcing, etc)	*Yes*	...
1.4.7	Are there regular audits of raw materia suppliers, regarding their sustainable development practices relating to SP4?	*Yes*	...

Production

Number	Question	Answer	Notes / Comments
	Sustainability principle 1 – In a sustainable society, nature is not subject to systematically increasing concentrations of substances from the earth's crust.	Yes, No, Don't know, Not applicable	
	Impact questions		
2.1.1	Is the production process free from process materials from the earth's crust that are scarce in nature? (e.g. Cu, Ag, Sn, Cd, Hg...)	*Yes*	...

2.1.2	Is production waste and emissions free from substances from the earth's crust that are scarce in nature?	*Yes*	...
2.1.3	Is the production process and facilities powered with fossil-free energy sources?	*Yes*	...
	Progress questions		
2.1.4	Are there targets and are actions being taken to phase out use of process materials originating from the earth's crust that are scarce in nature?	*Yes*	...
2.1.5	Are there targets and are actions being taken to achieve zero waste/emissions (of materials from the earth's crust) in production? (e.g. through choosing waste free production technology, smart design, efficiency measures, improving systems for waste handling /treatment/recycling/resue, production management, etc)	*Yes*	...
2.1.6	Are there targets and are actions being taken to minimise the use of raw materials and process materials originating from the earth's crust? (e.g. through eliminating waste, designing products that are simplified in terms of their production, lighter products, etc)	*Yes*	...
2.1.7	Are there targets and are actions being taken to improve energy efficiency and switch to fossil-free energy sources?	*Yes*	...
	Sustainability principle 2– In a sustainable society, nature is not subject to systematically increasing concentrations of substances produced by society.	Yes, No, Don't know, Not applicable	
	Impact questions		
2.2.1	Is the production process free from process materials consisting of substances produced by society that risk accumulating in nature?	*Don't know*	Kemisk pulping och sizing?
2.2.2	Is production waste and emissions free from substances produced by society that risk accumulating in nature?	*Yes*	...

2.2.3	Is the production process and facilities powered with energy sources that do not risk release of substances produced by society that risk accumulating in nature?	*Yes*	...
	Progress questions		
2.2.4	Are there targets and are actions being taken to phase out process materials consisting of substances produced by society that risk accumulating in nature?	*Yes*	...
2.2.5	Are there targets and are actions being taken to achieve zero waste/emissions* (of substances produced by society that risk accumulating in nature) in production? (e.g. through choosing waste free production technology, smart design, efficiency measures, improving systems for waste handling /treatment/recycling/resue, production management, etc)	*Yes*	...
2.2.6	Are there targets and are actions being taken to minimise the use of raw materials and process materials that consist of substances produced by society? (e.g. through eliminating waste, designing products that are simplified in terms of their production, lighter products, selecting production methods that are less demaning in terms of process sybstances produced by society, etc)	*Yes*	...
2.2.7	Are there targets and are actions being taken to improve energy efficiency and switch to energy sources that do not risk releasing substances produced by society that risk accumulating in nature?	*Yes*	...
	Sustainability principle 3 – In a sustainable society, nature is not subject to systematically increasing physical degradation.	Yes, No, Don't know, Not applicable	
	Impact questions		
2.3.1	Are process materials free from rare, threatened, endangered or structurally important organisms or species? (e.g. rare corals, kelp, shark fins, rhinoceros horns, top predators, etc)	*Yes*	...

2.3.2	Is systematic physical degradation of nature avoided during the production of the product? (e.g. through heating water, exessive water extraction, land conversion, habitat destruction, overfishing, bi-catch, deforestation, etc)	*Yes*	...
2.3.3	Is the production process and facilities powered with energy sources that do not contribute to systematic degradation of nature by physical means?	*Yes*	...
	Progress questions		
2.3.4	Are there targets and are actions being taken to ensure that rare, threatened, endagered or structurally important organisms or species are not used as process materials? (i.e. through sourcing, auditing, production process design/selection, etc)	*Yes*	...
2.3.5	Are there targets and are actions being taken to eliminate systematic physical degradation of nature connected to the production? (e.g. through selection and management of production technologies, efficiency measure, imrpoving systems for waste handling/treatment/recycling/use, etc)	*Yes*	...
2.3.6	Are there targets and are actions being taken to minimise the use of raw materials and process materials that contribute to systematic physical degradation of nature? (e.g. through eliminating waste, designing products that are simplified in terms of their production, lighter products, etc)	*Yes*	...
2.3.7	Are there targets and actions being taken to select and manage the production facilities in ways that avoid contributing to systematic physical degradation of nature? (e.g. through site selection, rehabilitation plans, staged operations, habitat management, fauna / flora protection zones, biodiversity efforts, etc)	*Yes*	...
	Sustainability principle 4 – In a sustainable society, people are not subject to conditions that systematically undermine their capacity to meet their needs.	Yes, No, Don't know, Not applicable	

	Impact questions		
2.4.1	Is production free from process substances whose use risk underminging people's capacity to meet their basic human needs*? (e.g. inherently unsafe substances, wasteful use given other societal needs, etc)	*Yes*	...
2.4.2	Are wages in production fair and is the long term wellbeing of local communities supported?	*Yes*	...
2.4.3	Do working conditions in production avoid violating human needs in a systematic way?	*Yes*	...
	Progress questions		
2.4.4	Are there targets and are actions being taken to ensure that there are no conditions in 'production' that systematically hinder people from fullfilling their basic human needs*?	*Yes*	...
2.4.5	Are there targets and are actions being taken to ensure that production wages are fair and that the long term wellbeing of local communities is supported?	*Yes*	...
2.4.6	Are short and long term negative health implications for workers in production decreasing?	*Yes*	...
2.4.7	Are there targets and are actions being taken to phase out production processes and process materials/substances that are hazardous to human health?	*Yes*	...

Packaging, distribution and retail

Number	Question	Answer	Notes / Comments
	Sustainability principle 1 – In a sustainable society, nature is not subject to systematically increasing concentrations of substances from the earth's crust.	Yes, No, Don't know, Not applicable	

	Impact questions		
3.1.1	Is primary, secondary and tertiary packaging free from substances from the earth's crust that are scarce in nature? (e.g. Cu, Ag, Sn, Cd, Hg, etc)	*Yes*	...
3.1.2	Is the distribution of the product (including transportation, warehousing and retail) free of waste/emissions in the form of substances from the earth's crust that are scarce in nature?	*No*	...
3.1.3	Are all energy requirements for packaging production and distribution powered with fossil-free energy?	*No*	...
	Progress questions		
3.1.4	Are there targets and are actions being taken to phase out the use of packaging materials from the earth's crust that are scarce in nature?	*Yes*	...
3.1.5	Are there targets and are actions being taken to optimise distribution (including transportation, warehousing and retail) to avoid release of substances of the earth's crust that are scarce in nature? (e.g. through reducing transport distances, changing transport modes, removing middle hands, etc)	*Yes*	...
3.1.6	Are there targets and are actions being taken to phase out fossil energy sources from transportation, warehousing and retail?	*No*	...
3.1.7	Are there clear purchasing guidelines for suppliers of packaging, warehousing and transports, relating to sustainable use and management of substances from the earth's crust?	*Yes*	...
	Sustainability principle 2– In a sustainable society, nature is not subject to systematically increasing concentrations of substances produced by society.	Yes, No, Don't know, Not applicable	
	Impact questions		
3.2.1	Is primary, secondary and tertiary packaging free from substances produced by society that risk accumulating in nature?	*No*	Plast vid frakt? måste garantera vattentålighet typ

3.2.2	Is the distribution of the product (including transportation, warehousing and retail) free from waste/emissions in the form of substances produced by society that risk accumulating in nature?	*No*	Plast i sådana fall
3.2.3	Are all energy requirements for packaging production and distribution powered with energy sources that do not generate or depend on substances produced by society that risk accumulating in nature?	*Don't know*	...
	Progress questions		
3.2.4	Are there targets and are actions being taken to phase out the use of substances produced by society that risk accumulating in nature from packaging?	*Don't know*	...
3.2.5	Are there targets and are actions being taken to achieve zero packaging waste * in the form of substances produced by society that risk accumulating in nature?	*Yes*	...
3.2.6	Are there targets and are actions being taken to optimise distribution (including transportation, warehousing and retail) to avoid release of substances produced by society that risk accumulating in nature? (e.g. through reducing transport distances, changing transport modes, removing middle hands, etc)	*Yes*	Vi bestämmer produkternas utformning och på så vis kan transport och volym t.ex. minimeras.
3.2.7	Are there clear purchsing guidelines for suppliers of packaging, warehousing and transports, relating to sustainable use and management of substances produced by society?	*Yes*	...
	Sustainability principle 3 – In a sustainable society, nature is not subject to systematically increasing physical degradation.	Yes, No, Don't know, Not applicable	
	Impact questions		
3.3.1	Is systematic physical destruction of nature avoided in the extraction and production of primary, secondary and tertiary packaging materials?	*Yes*	...

3.3.2	Does the distribution of the product (including transportation, warehousing and retail) avoid contributing to systematic physical degradation of nature?	*Yes*	...
3.3.3	Is packaging production and distribution powered with energy sources that do not contribute to systematic physical degradation of nature?	*Don't know*	...
	Progress questions		
3.3.4	Are there targets and actions to ensure that the extraction and production of packaging materials materials does not contribute to systematic physical degradation of nature?	*Yes*	...
3.3.5	Are there targets and are actions being taken to ensure that packaging materials do not end up in landfill?	*Don't know*	Utanför Sverige, vet inte. Svårt.
3.3.6	Are there targets and actions to minimise the physical degradation of nature due to distribution?	*Yes*	...
3.3.7	Are there clear purchasing guidelines for suppliers of packaging, warehousing and transports, relating to sustainable physical use of natural systems?	*Yes*	...
	Sustainability principle 4 – In a sustainable society, people are not subject to conditions that systematically undermine their capacity to meet their needs.	Yes, No, Don't know, Not applicable	
	Impact questions		
3.4.1	Is packaging and distribution free from substances that risk systematically undermining people's capacity to meet their basic human needs?	*Yes*	...
3.4.2	Are packaging and distribution services sourced fairly and in ways that support the long term wellbeing of local communities?	*Yes*	...
3.4.3	Do working conditions in packaging and distribution avoid violating human needs in a systematic way?	*Yes*	...
	Progress questions		
3.4.4	Are there targets and are actions being taken to ensure that there are no conditions in 'packaging and distribution' that systematically hinder people from fullfilling their basic human needs*?	*Yes*	...

3.4.5	Are there targets and are actions being taken to ensure that production wages are fair and that the long term wellbeing of local communities is supported?	*Yes*	...
3.4.6	Is a Code of Conduct* integrated into all packaging and distribution purchasing decisions to help meet SP4?	*Yes*	...
3.4.7	Are there regular audits of packaging and distribution suppliers regarding their sustainable development practices relating to SP4?	*Yes*	...

Product use & maintenance

Number	Question	Answer	Notes / Comments
	Sustainability principle 1 – In a sustainable society, nature is not subject to systematically increasing concentrations of substances from the earth's crust.	Yes, No, Don't know, Not applicable	
	Impact questions		
4.1.1	Is the use and maintenance of the product free from substances from the earth's crust that are scarce in nature*? (e.g. Cu, Ag, Sn, Cd, Hg, etc)	*Yes*	...
4.1.2	Is leakage, from the product, of substances from the earth's crust that are scarce in natutre avoided during the use phase?	*Yes*	...
4.1.3	Is the use and maintenance of the product powered with fossil-free energy?	*Not applicable*	...
	Progress questions		
4.1.4	Are there targets and are actions being taken to phase out the use of substances (and fossil energy) from the earth's crust that are scarce in nature* from the use and maintenance of the product?	*Not applicable*	...

4.1.5	Are there targets and are actions being taken to minimise the amount of substances from the earth's crust that are needed throughout the use phase, including any fossil energy use, mined materials, etc? (e.g. through user training, behavioural steering, smart design and selection of materials, mainenance free solutions, provision of benign cleaning fluids, optimisation services, etc)	*Not applicable*	...
4.1.6	Are there targets and are actions being taken to minimise use phase waste (or unintended leakage or dispersion) in the form of materials from the earth's crust that are scarce in nature?	*Not applicable*	...
4.1.7	Are there targets and are actions being taken to optimise the life span of the product and any of its' SP1 components?	*Yes*	...
	Sustainability principle 2– In a sustainable society, nature is not subject to systematically increasing concentrations of substances produced by society.	Yes, No, Don't know, Not applicable	
	Impact questions		
4.2.1	Is the use and maintenance of the product free from substances produced by society that risk accumulating in nature??	*Not applicable*	...
4.2.2	Is leakage, from the product, of substances produced by society that risk accumulating in nature avoided during the use phase?	*Yes*	...
4.2.3	Is the use and maintenance of the product powered with energy sources that do not generate or depend on substances produced by society that risk accumulating in nature?	*Not applicable*	...
	Progress questions		
4.2.4	Are there targets and are actions being taken to phase out the use of substances (and such energy) produced by society that risk accumulating in nature from the use and maintenance of the product?	*Not applicable*	...

4.2.5	Are there targets and are actions being taken to minimise the amount of substances produced by society, that risk accumulating in nature, needed throughout the use phase, including any related energy? (e.g. through user training, behavioural steering, smart design and selection of materials, mainenance free solutions, provision of benign cleaning fluids, optimisation services, etc)	*Not applicable*	...
4.2.6	Are there targets and are actions being taken to minimise use phase waste (or unintended leakage or dispersion) in the form of substances produced by society that risk accumulating in nature?	*Not applicable*	...
4.2.7	Are there targets and are actions being taken to optimise the life span of the product and any of its' SP2 components?	*Don't know*	...
	Sustainability principle 3 – In a sustainable society, nature is not subject to systematically increasing physical degradation.	Yes, No, Don't know, Not applicable	
	Impact questions		
4.3.1	Does the intended use of the product avoid contributing to systematic physical degredation of nature?	*Not applicable*	...
4.3.2	Are materials used for the operation and maintenance ofthe product extracted and produced in ways that avoid contributing to systematic physical degradation of nature?	*Not applicable*	...
4.3.3	Is the use and maintenance of the product powered with energy sources that do not contribute to systematic degradation of nature by physical means?	*Not applicable*	...
	Progress questions		
4.3.4	Are there targets and are actions being taken to eliminate any physical degradation of nature that occurs as a result of the intended use?	*Not applicable*	...

4.3.5	Are there targets and are actions being taken to minimise the amount of materials needed throughout the use phase (including consequences of energy use) that contribute to systematic physical degradation of nature? (e.g. through user training, behavioural steering, smart design and selection of materials, mainenance free solutions, provision of benign cleaning fluids, optimisation services, etc)	*Not applicable*	...
4.3.6	Are there targets and are actions to ensure that materials used for the operation or maintenance of the product do not contribute to systematic physical degredation of nature?	*Not applicable*	...
4.3.7	Are there targets and are actions being taken to optimise the life span of the product and any of its' components/materials that originate from nature?	*Yes*	...
	Sustainability principle 4 – In a sustainable society, people are not subject to conditions that systematically undermine their capacity to meet their needs.	**Yes, No, Don't know, Not applicable**	
	Impact questions		
4.4.1	Does the intended use of the product avoid systamtically undermining the user's or surrounding community's capacity to meet their basic human needs?	*Yes*	...
4.4.2	Does product use contribute to building a culture of need fullfiment rather than promoting a culture of linear consumtion?	*Yes*	...
4.4.3	Are there zero significant health risks (both short and long term) related to the use and maintenance of the product?	*Yes*	...
	Progress questions		
4.4.4	Are there targets and are actions being taken to ensure that there are no conditions, connected to the use an maintenance of the product, that systematically hinder people from fullfilling their basic human needs*?	*Yes*	...
4.4.5	Are there targets and actions to maximise the utility (i.e. the amount of need fullfillment) the user(s) can get from the product throughout its' life span?	*Yes*	...

4.4.6	Are there targets and are actions being taken to raise awareness among users regarding the sustainability attributes and footprint of the product?	*Yes*	...
4.4.7	Are there targets and are actions being taken to ensure that the product remains functional and safe for as long as possible?	*No*	...

Product fate / End of Life

Number	Question	Answer	Notes / Comments
	Sustainability principle 1 – In a sustainable society, nature is not subject to systematically increasing concentrations of substances from the earth's crust.	Yes, No, Don't know, Not applicable	
	Impact questions		
5.1.1	Is release of substances from the earth's crust that are scarce in nature avoided at the end of life of the product, including processing and final fate?	*Yes*	...
5.1.2	Are there well-functioning systems in place in society for reuse and recycling of the product and its' substances from the earth's crust?	*Yes*	...
5.1.3	Is the end of life product recovery, transports and processing powered with fossil-free energy sources?	*No*	...
	Progress questions		
5.1.4	Are there targets and are actions being taken to move towards fully closed material loops regarding substances from the earth's crust that are scarce in nature?	*Not applicable*	...
5.1.5	Are there targets and are actions being taken to ensure that there are well functioning systems for product recovery, reuse and recycling to ensure that substances from the earth's crust that are scarce in nature are not released into nature?	*Not applicable*	...

5.1.6	Are there targets and are actions being taken to ensure that the product itself is designed for easy recovery and reuse or recycling of components or substances from the earth's crust that are scarce in nature?	*Yes*	...
5.1.7	Are there targets and are actions being taken to actively collaborate with users to work on product-recycling issues as they relate to materials from the earth's crust?	*Not applicable*	...
	Sustainability principle 2– In a sustainable society, nature is not subject to systematically increasing concentrations of substances produced by society.	Yes, No, Don't know, Not applicable	
	Impact questions		
5.2.1	Is release of substances produced by society that risk accumulating in nature avoided at the end of life of the product, including processing and final fate?	*Yes*	...
5.2.2	Are there well-functioning systems in place in society for reuse and recycling of the product and its' substances that are produced by society?	*Yes*	...
5.2.3	Is the end of life product recovery, transports and processing powered with energy sources that do not generate or depend on substances produced by society that risk accumulating in nature	*Yes*	...
	Progress questions		
5.2.4	Are there targets and are actions being taken to move towards fully closed material loops regarding substances produced by society that risk systamtically increasing in nature?	*Yes*	...
5.2.5	Are there targets and are actions being taken to ensure that there are well functioning systems for product recovery, reuse and recycling to ensure that substances produced by society that risk accumulating in nature are not released into nature?	*Yes*	...
5.2.6	Are there targets and are actions being taken to ensure that the product itself is designed for easy recovery and reuse or recycling of substances produced by society that risk accumulating in nature?	*Yes*	...

5.2.7	Are there targets and are actions being taken to actively collaborate with users to work on product-recycling issues as they relate to substances produced by society?	*Yes*	...
	Sustainability principle 3 – In a sustainable society, nature is not subject to systematically increasing physical degradation.	Yes, No, Don't know, Not applicable	
	Impact questions		
5.3.1	Is systematic physical degradation of nature avoided at the end of life of the product, including processing and final fate?	*Yes*	...
5.3.2	Are there well-functioning systems in place in society for reuse and recycling of the product and its' materials that originate from nature?	*Yes*	...
5.3.3	Is the end of life product recovery, transports and processing powered with energy sources that do not contribute to the systematic degrdation of nature?	*No*	...
	Progress questions		
5.3.4	Are there targets and are actions being taken to move towards fully closed material loops regarding materials originating from nature? (i.e. either in technical loops or in natural loops)	*Yes*	...
5.3.5	Are there targets and are actions being taken to ensure that there are well functioning systems for product recovery, reuse and recycling to minimise the amount of materials that are sent to landfill?	*Yes*	...
5.3.6	Are there targets and are actions being taken to ensure that the product itself is designed for easy recovery and reuse or recycling of materials originating from nature?	*Yes*	...
5.3.7	Are there targets and are actions being taken to actively collaborate with users to work on product-recycling issues as they relate to natural resources?	*Yes*	...
	Sustainability principle 4 – In a sustainable society, people are not subject to conditions that systematically undermine their capacity to meet their needs.	Yes, No, Don't know, Not applicable	
	Impact questions		

5.4.1	Are there zero significant health risks (both short and long term) related to the end of life recovery, handling, processign and potential disposal of the product?	*Yes*	...
5.4.2	Are wages fair for people working with the end of life recovery, handling and processing of the product and do these things happen in ways that support the long term wellbeing of local communities?	*Yes*	...
5.4.3	Do working conditions in the recovery, handling and processing of the product at the end of life avoid violating basic human needs in a systematic way?	*Yes*	...
	Progress questions		
5.4.4	Are there targets and are actions being taken to ensure that there are no conditions connected to the recovery, handling and processing of the product at the end of life that systematically hinder people from fullfilling their basic human needs?	*Yes*	...
5.4.5	Are there targets and are actions being taken to ensure that there are no negative community impacts connected to the end of life recovery, processing or fate of the product?	*Yes*	...
5.4.6	Are there targets and are actions being taken to ensure that users know how the product should be handled most sustainably at the end of life?	*Yes*	...
5.4.7	Do end of life service providers have robust and enforced health and safety policies?	*Don't know*	...

APPENDIX II

– SEGMENTS IN THE GPC

Arts/Crafts/Needlework	Live Animals
Audio/Visual/Photography	Lubricants
Automotive	Music
Beauty/ Personal Care/ Hygiene	Personal Accessories
Building Products	Pet Care/Food
Camping	Plumbing/Heating/Ventilation/Air/Conditioning
Cleaning/Hygiene Products	Safety Protection-DIY
Clothing	Safety/Security/Surveillance
Communications	Sports Equipment
Computing	Stationery/Office Machinery/Occasion Supplies
Crops	Storage/Haulage Containers
Cross Segment	Textual Printed Reference Materials
Electrical Supplies	Tool/Storage/Workshop/Aids
Food/Beverage/Tobacco	Tools/Equipment Hand
Footwear	Tools/Equipment Power
Fuels/Gases	Toy
Healthcare	
Home Appliances	
Horticulture	
Household/Office Furniture/Furnishings	
Kitchen Merchandise	
Lawn/Garden Supplies	

APPENDIX III

– SEARCH AREA MATRIX

	Aging population, increased need for disposablegoods in e.g. hospitals	Environmental need	Other material for similar usage are lasting longer than the use phase (too good)	Increased need for recycling	Digitalization leeds decreses the need for priced media, the raw material need to be used in other applications	A large trend towards outdoor lifestyle and traveling	Increasing population, growing middle class increases the need for (packaged) products	The large amount of refugees increases the demand for disposable products	Environmental trend - non toxic	Environmental trend - non plastic	Environmental trend - consumers are more aware	A large interest from the society	A large interest from the society
made to messure	×	×			×	×	×	×					
experience possibilities (eco vs plastic)	×	×	×				×		×				
in other raw material	×		×			×	×	×	×		×		
smooth surface finish	×					×		×					
renewable resource								×	×				
non-toxic	×		×			×	×		×				
no additives	×						×						
possibility for upcycling	×			×			×	×					
recyclable											×		
low density	×		×			×	×	×					
cheap	×		×			×	×	×	×				
similar to plastic (could replace)	×					×	×	×		×	×		
possibility for short cycles if high pressure			×										
water saving manufacturing							×						
possibility for complex 3D shapes	×		×			×	×	×					
printable	×		×	×	×	×	×						
resistance to corrosion						×							
could be locally produced around the world	×					×	×						
decomposable	×		×		×	×	×	×	×				
short lifespan	×					×	×	×	×	×			
not bound to convention << small company					×								
new business area, innovation		×			×								

APPENDIX IV

– APPLICATIONS FROM CES EDUPACK 2016

table top	medium density fibreboard
drawer	medium density fibreboard
drawer front	medium density fibreboard
cabinet carcasses	medium density fibreboard
toy, bucket, shovel	Polyethylene high density
bowl	Polyethylene high density
box	Polyethylene high density
food packaging	PLA polyactide, SBS
bottle	PLA polyactide
cold drink cup	PLA polyactide
electronic case	PLA polyactide
flower pot	PLA polyactide
diaper	PLA polyactide
protective goggles	PMMA
sign	PMMA
cosmetic case	PP, CA
pen	PP, CA
tray	PP
battery pack	PP
bottle cap	PP
diffuser	PP
cup	PP, SBS
cuttlery	PP
lid	PP
palette	PP
painting tool	PP
frame for glasses	CA
brush handle	CA
filter	Paper

APPENDIX V

– SEGMENTATION OF APPLICATIONS

SPORTS	HOME & INTERIOR	SANITARY & HYGIENE	PACKAGING	EATING	CLEANING
helmet	matches	wee funnel for women	shock absorbant structure	baby bib	compost bucket
leg protection	matchbox	potty	salt & pepper shaker	tray	tissue despenser
suspensoar	picture frame	plackers	floss container	disposable plate	toilet brush
bumslider	kids furniture	disposable toothbrush	bag in box (for wine)	disposable cup	shower strainer
freesbee	corner protection (baby)	camping toilet	nespresso capsule	disposable cuttlery	dish brush
GAMES & MUSIC	safety protection for sockets (baby)	dustbin for dipers	bag clip	cup for medicine	waste bin
board game	stucco	**ANIMALS**	diveder in chocolat or cookie box	baby table ware	broom handle
doll furniture	cabinet carcasses	seed dispenser	give away packaging	fruit case	spray bottle
toy railway set	box	litter box	spool for gift lace	cutting board	broom
masquerade costumes and masks	flowerpot	birdhouse	take away packaging	wine cooler	shower scraper
happy meal toy	tea light	cat clawing board	cosmetic packaging	beer opener	bag for vacuum cleaner
scientific toy (atomic model, human body etc.)	fire alarm	food bowl	spice jar	coaster	**CONSTRUCTION & TOOLS**
building blocks	baby safety products	automatic pet food bowl	yoghurt container	bowl	wallanchors/plug
vuvuzela	wine rack	**ELECTRONICS**	chewing gum packaging	**HEALTHCARE**	grass collector for lawn mower
pick	balcony furniture	analoge amplifier	bottle	crutch	ice scraper
3D puzzle	baby carriage	disposable headphones for airplanes	cold drink cup	plaster/support/sling	white board eraser
puzzle	temporary furniture	3D glasses	cup lid	disposable shooes	knife case
childrens books with embossed pages	key holder	mobile phone case	**PERSONAL CARE**	cooling bag for vaccine	folding rule
baby exersisers	baby nest	disposable cameras	garment roller	dosett	tool box
COOKING	curtain pole	breadboard	disposable hairbrush	rescue kit	cable marker
tea strainer	lamp stand/base	miniature fan	odor control for shoes	wheelchair components	shovel
coffiee strainer	display holder	electronic chassi	clothes hanger	**SAFETY EQUIPMENT**	bucket
disposable baking form	table top	flash light	moister absorber	construction helmets	ARTS & CRAFTS
dispenser for sprouting	drawer	bike lamp	booties for e.g. hospitals	ear protection	bobbin
frosting nozzle	**HOLIDAY & CELEBRATION**	head lamp	shoe last	knee protection	paint tray
disposable barbecue	party hat	speaker	coffin	spare tire	handle for paint roller or brush
cooking equipment for camping	party light	microphone	urn	protective shoes	knitting needle
	piniata		suitcase	sign	pen/pencil
	fire work				
	seasonal ornaments				

APPENDIX VI

– FIRST SCREENING OF APPLICATIONS

SPORTS	HOME & INTERIOR	SANITARY & HYGIENE	PACKAGING	EATING	CLEANING
helmet	**matches**	**wee funnel for women**	**shock absorbant structure**	**baby bib**	**compost bucket**
leg protection	**matchbox**	**potty**	**salt & pepper shaker**	**tray**	**tissue despenser**
suspensoar	picture frame	**plackers**	**floss container**	disposable plate	toilet brush
bumslider	kids furniture	disposable toothbrush	**bag in box (for wine)**	disposable cup	shower strainer
freesbee	corner protection (baby)	camping toilet	nespresso capsule	disposable cuttlery	dish brush
GAMES & MUSIC	safety protection for sockets (baby)	dustbin for dipers	bag clip	cup for medicine	waste bin
board game	stucco	**ANIMALS**	diveder in chocolat or cookie box	baby table ware	broom handle
doll furniture	cabinet carcasses	**seed dispenser**	give away packaging	fruit case	spray bottle
toy railway set	box	**litter box**	spool for gift lace	cutting board	broom
masquerade costumes and masks	flowerpot	birdhouse	take away packaging	wine cooler	shower scraper
happy meal toy	tea light	cat clawing board	cosmetic packaging	beer opener	bag for vacuum cleaner
scientific toy (atomic model, human body etc.)	fire alarm	food bowl	spice jar	coaster	**CONSTRUCTION & TOOLS**
building blocks	baby safety products	automatic pet food bowl	yoghurt container	bowl	**wallanchors/plug**
vuvuzela	wine rack	**ELECTRONICS**	chewing gum packaging	**HEALTHCARE**	**grass collector for lawn mower**
pick	balcony furniture	**analoge amplifier**	bottle	**crutch**	ice scraper
3D puzzle	baby carriage	**disposable headphones for airplanes**	cold drink cup	**plaster/support/sling**	white board eraser
puzzle	temporary furniture	3D glasses	cup lid	disposable shooes	knife case
childrens books with embossed pages	key holder	mobile phone case	**PERSONAL CARE**	cooling bag for vaccine	folding rule
baby exersisers	baby nest	disposable cameras	**garment roller**	dosett	tool box
COOKING	curtain pole	breadboard	disposable hairbrush	rescue kit	cable marker
tea strainer	lamp stand/base	miniature fan	odor control for shoes	wheelchair components	shovel
coffiee strainer	display holder	electronic chassi	clothes hanger	**SAFETY EQUIPMENT**	bucket
disposable baking form	table top	flash light	moister absorber	**construction helmets**	**ARTS & CRAFTS**
dispenser for sprouting	drawer	bike lamp	booties for e.g. hospitals	ear protection	**bobbin**
frosting nozzle	**HOLIDAY & CELEBRATION**	head lamp	shoe last	knee protection	**paint tray**
disposable barbecue	party hat	speaker	coffin	spare tire	**handle for paint roller or brush**
cooking equipment for camping	party light	microphone	urn	protective shoes	knitting needle
	piniata		suitcase	sign	pen/pencil
	fire work				
	seasonal ornaments				

APPENDIX VII

– EVALUATION MATRIX FIRST PHASE

	WHEIGHTING	Plaster/Support/Sling	Shock Absorbation Structure	Crutch Handel	Bobbin (trådrulle)	Wee funnel	Temporary helmet (sport or builder)	Disposable Potty Insert	Analogue Amplifier	Paint Tray	Garment Roller	Bag in Box	Floss Container/Plackers	Salt'n'Pepper Shakers	Bib	Litter Box	Brush/roller Handle	Compost Bucket (instead of bag)	Serving Tray	Baking Tin	Matcher and/or Matchbox	Tea or Coffee Strainer	Dispenser for Sprouting	Tissue Despenser	Seed Dispenser	Wallanchor/Plug	Grass Collector for Mower	Headphones (giveaway)
Appropriate lifespan	2	16	20	14	20	16	14	16	20	14	18	20	16	16	16	14	12	20	12	16	18	14	12	14	12	10	14	12
Benifit different stakeholders	1	8	8	9	8	6	8	8	7	7	8	9	7	6	7	6	7	5	7	6	6	6	5	7	5	7	6	7
Coherent aestetics/expression/experience	1	9	8	8	10	10	6	10	10	10	9	9	9	9	9	8	8	7	7	8	9	8	8	10	7	6	6	7
Comply with standards, rules & regulations	2	18	16	18	18	14	8	20	20	20	20	18	14	14	18	20	18	12	20	12	20	14	18	18	16	10	12	10
Enable closed loop system	1	7	10	8	10	6	10	6	10	3	10	10	7	7	8	9	6	6	10	7	6	6	9	10	6	2	6	3
Full potential of material properties	2	18	18	18	16	18	18	16	14	14	18	14	14	12	14	12	16	12	16	12	12	12	12	10	14	10	12	10
Innovation level	1	8	8	9	7	7	8	5	9	6	6	5	5	6	5	4	6	4	4	5	5	4	4	4	5	5	5	8
Positive societal impact	2	20	14	20	10	18	18	10	10	12	6	8	10	8	10	6	8	10	4	6	4	8	10	4	8	14	6	8
PulpPack give application added value	2	18	18	18	14	20	16	14	12	16	12	12	12	14	10	10	12	16	6	14	12	12	6	8	12	12	8	6
Tend to future market	2	16	16	16	14	20	20	12	12	14	12	14	16	18	10	12	14	12	12	14	12	14	10	10	10	10	8	2
Viable manufacturing	2	16	16	12	18	14	18	20	12	18	14	12	16	14	16	20	14	18	18	16	12	16	18	10	10	14	16	8
Profitability	1	7	8	7	9	5	8	7	7	8	7	8	8	7	7	7	7	4	7	6	6	7	6	5	4	8	7	4
TOTAL SCORE		161	160	157	154	154	152	144	143	142	140	139	134	131	130	128	128	126	123	122	122	121	118	110	109	108	106	85

	WHEIGHTING	Wee funnel	Shock Absorbation Structure	Analogue Amplifier	Bobbin (trådrulle)	Plaster/Support/Sling	Crutch Handel	Temporary helmet (sport or builder)	Salt'n'Pepper Shakers	Garment Roller	Floss Container/Plackers	Paint Tray	Disposable Potty Insert	Bag in Box	Tea or Coffee Strainer	Brush/roller Handle	Matcher and/or Matchbox	Dispenser for Sprouting	Baking Tin	Bib	Tissue Despenser	Compost Bucket (instead of bag)	Serving Tray	Seed Dispenser	Litter Box	Wallanchor/Plug	Headphones (giveaway)	Grass Collector for Mower
Appropriate lifespan	2	16	20	20	20	16	14	14	16	18	16	14	16	20	14	12	18	12	16	16	14	20	12	12	14	10	12	14
Benifit different stakeholders	1	6	8	7	8	8	9	8	6	8	7	7	8	9	6	7	6	5	6	7	7	5	7	5	6	7	7	6
Coherent aestetics/expression/experience	1	10	8	10	10	9	8	6	9	9	9	10	10	9	8	8	9	8	8	9	10	7	7	7	8	6	7	6
Comply with standards, rules & regulations	2	14	16	20	18	18	18	8	14	20	14	20	20	18	14	18	20	18	12	18	18	12	20	16	20	10	10	12
Enable closed loop system	1	6	10	10	10	7	8	10	7	10	7	3	6	10	6	6	6	9	7	8	10	6	10	6	9	2	3	6
Full potential of material properties	2	18	18	14	16	18	18	18	12	18	14	14	16	14	12	16	12	12	12	14	10	12	16	14	12	10	10	12
Innovation level	1	7	8	9	7	8	9	8	6	6	5	6	5	5	4	6	5	4	5	5	4	4	4	5	4	5	8	5
Positive societal impact	2	18	14	10	10	20	20	18	8	6	10	12	10	8	8	8	4	10	6	10	4	10	4	8	6	14	8	6
PulpPack give application added value	2	20	18	12	14	18	18	16	14	12	12	16	14	12	12	12	12	6	14	10	8	16	6	12	10	12	6	8
Tend to future market	2	20	16	12	14	16	16	20	18	12	16	14	12	14	14	14	12	10	14	10	10	12	12	10	12	10	2	8
Viable manufacturing	2	14	16	12	18	16	12	18	14	14	16	18	20	12	16	14	12	18	16	16	10	18	18	10	20	14	8	16
Profitability	1	5	8	7	9	7	7	8	7	7	8	8	7	8	7	7	6	6	6	7	5	4	7	4	7	8	4	7
Buzz value (marketing)	2	18	16	18	12	12	14	14	18	8	12	8	10	12	10	8	8	8	6	6	8	10	6	6	6	6	12	6
Can be used as giveaway	2	20	12	20	14	12	12	18	20	16	18	6	4	4	16	10	16	14	10	8	14	4	6	12	2	10	14	2
Possibility to make prototype	3	30	21	24	24	15	12	6	21	21	21	27	15	15	21	21	18	24	24	12	21	9	12	18	6	18	15	6
SCORE INC. PROJECT CRITERIA		222	209	205	204	200	195	190	190	185	185	183	173	170	168	167	164	164	162	156	153	149	147	145	142	142	126	120

APPENDIX VIII

– EXTENDED EVALUATION MATRIX SECOND PHASE