NUTRIENTS REMAIN NUTRIENTS: A VIABLE CRADLE TO CRADLE PRINCIPLE FOR BAMBOO PRODUCTS?

Jyväskylä University
School of Business and Economics

Master's Thesis

2020

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Subject: Corporate Environmental Management
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ABSTRACT

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Title
Nutrients remain Nutrients: A viable Cradle to Cradle principle for bamboo products?

Subject	Type of work
Corporate Environmental Management	Master's Thesis
Date	Number of pages
23 November 2020	87

Abstract
Replacing abiotic materials with biotic materials becomes more needed in today's polluted world than ever. At the same time, the concept of a circular economy becomes more prominent to manage these material flows. Bamboo is a great biotic replacement option for many abiotic materials, and the principle 'Nutrients remain Nutrients' of the Cradle to Cradle (C2C) approach is seen as one of the founding theories for the circular economy. Because of the lack of publications combining the C2C principle with bamboo, this research aims to investigate to what extent this particular principle can be seen as a viable option for Dutch and German bamboo product manufacturers.

To conduct the research, a qualitative approach was applied. In total, 11 semi-structured interviews were conducted with manufacturers from the industries of consumer items, construction and finishing materials, furniture, and textiles. The data provides valuable insights into current practices as well as possible challenges and needs with the principle.

The research findings reveal that the viability of the proposed cycles depends on the product composition and product design, the cost-benefit-ratio, the role of customers/consumers as well as the role of the manufacturer, suppliers and partnerships, the industry and market set up, and given infrastructures and technology on hand. Therefore, this research concludes that the principle is viable if the circumstances are right. However, the majority of the manufacturers is not able to adopt the principle in its entirety as it faces certain challenges. Despite finding similarities between industries, the great product range requires further investigation with a more specific focus on one particular industry or product.

Key words
Bamboo, Cradle to Cradle, circular economy, German manufacturer, Dutch manufacturer, Nutrients remain Nutrients

Place of storage
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ACKNOWLEDGEMENTS

First and foremost, I would like to thank all the participating companies for taking the time to provide valuable insights into their operations and opinions. I would also like to thank them for the credit of trust that I will handle this internal information with care. Special thanks go to the following company representatives (stated in no particular order): Ekaterina Smid (Biofutura), Götz Schmitt (GS Götz Schmitt), Koen Ottes (KOSA Bamboo), Joost Marienhoff and Ingo Schetzberg (Bamboo-House.de), Paul Bloemers (Bloooms), and Amar de Winter (Nooboo). Furthermore, I would like to thank DeinBambuswald and Pandoo for participating, as well as the three company representatives who would like to remain anonymous. Additionally, I would like to thank my thesis supervisor Marileena Mäkelä for providing guidance and feedback during the writing process. Moreover, I would like to thank my fellow students, who have been part of my thesis group, for giving new ideas and perspectives on my writing.

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LIST OF ACRONYMS AND ABBREVIATIONS

C2C = Cradle to Cradle
CE = Circular Economy
CSR = Corporate Social Responsibility
DE = Germany
EPEA = Environmental Protection Encouragement Agency
EU = European Union
HS = Harmonized System
LCA = Life Cycle Assessment
MBDC = McDonough Braungart Design Chemistry, LLC
MDF = Medium-Density Fibre
NL = The Netherlands
PoS = Product of Service
SME = Small and Medium-Sized Enterprise(s)

1 INTRODUCTION

This section of the report is intended for providing an introduction to this research. For this, the first step is to present background information to grasp the context of this research. Afterwards, it will be presented what the motivation for this research is on a personal and academic level. Then, the research aim as well as the research questions are presented. Finally, the structure of this thesis is presented.

1.1 Background

The extent of the current resource depletion as it is necessary for a standard of living in rich Western countries, like the ones in Europe, is unsustainable as there are simply not enough resources on the planet for all nations equally (O'Neill, 2018; Gabbatiss, 2018). To counteract on these negative ongoing practices and contribute to sustainable development, it is crucial to look at what raw materials are used to produce products and services and replace unsustainable materials with sustainable ones, such as regenerative materials (Feiel et al., 2019). One of these regenerative materials is the grass Bamboo that, thanks to its unique features and versatility, is able to tackle many elements addressed by the Sustainable Development Goals such as poverty reduction, energy, housing and urban development, sustainable production and consumption, climate change and the land degradation (INBAR, 2015). Although bamboo is not native to the European continent (Lucas, 2013), there is a demand for bamboo and therefore it is frequently imported from main producers in China (INBAR, 2019; CBI, 2017). Bamboo has also attracted the attention of European businesses and the European scientific community to see bamboo's performance in an industrial context, such as for the carbon footprints of bamboo and how it can contribute to reversing climate change (van der Lugt & Vogtländer, 2015).

Another element that needs to be looked at when discussing the implementation of sustainable raw materials, is the idea of a circular economy (Feiel et al., 2019). It is often seen as an ideal solution for tackling multiple Sustainable Development Goals at the same time (Schroeder et al., 2019). International organisations and scientists also recognise the potential of bamboo within a circular economy (INBAR, 2019; van der Lugt & King, 2019). The idea of a circular economy is influenced by many concepts, like the concept of Cradle to Cradle (C2C), which overlaps to a great deal with other concepts in this area (van Dijk et al., 2014). The concept's first principle of 'Nutrients remain Nutrient' addresses the material usage that plays a vital role in sustainable development (Feiel et al., 2019; McDonough & Braungart, 2002). Within Europe, C2C gained popularity in the Netherlands and has huge potential in Germany (Poprawa, 2012).

1.2 Motivation for the Research

The motivation for this research is based on personal interest as well as the current lack of scientific literature. On a personal level, bamboo, with its wide range of product applicability and its great potential to shift the current unsustainable and irretrievable resource depletion to the use of regenerative material, makes it an interesting and important raw material to research on. With bamboo's versatility, it also allows exploring practices in many different industries and their different reasons for making decisions. Furthermore, exploring bamboo through the lens of C2C allows covering another personal interest. The approach of C2C to tackle product design from an angle of effectiveness with an outcome of a positive footprint rather than the approach of conventional concepts based on efficiency with the attempt to reduce negative footprint makes it an interesting take on the circular economy.

On a scientific level, bamboo has huge potential to replace unsustainable materials, such as plastics, metals and others (Chaowana, 2013). However, as bamboo is a raw material and needs to be processed or requires other materials to make products out of it, it creates conflicts when applying a circular economy approach (van der Lugt & King, 2019). Literature that addresses bamboo in the context of a circular economy is limited to a few authors only. Furthermore, current scientific research mainly looks at one specific industry and does not explore bamboo as a raw material across different industries. Additionally, there was no literature found that conducted research on bamboo with a C2C approach. Therefore, exploring bamboo through the C2C approach would enrich the current scientific literature. The motivation to focus on the first principle 'Nutrients remain Nutrients' only, is based on the fact that it is identified as the most relevant one from the concept's point of view, as well as it contributes the most to attempt to achieve the Sustainable Development Goals (Toxopeus et al., 2015; Feiel et al., 2019).

Focusing on companies and distributors in the Netherlands and Germany is based on personal and scientific interest. As an author growing up in Germany as well as living and studying in the Netherlands, exploring the bamboo industry within these countries can offer great networking opportunities. From a scientific point of view, the Netherlands is the biggest importer of bamboo within the European Union, followed by other countries like Germany that is ranked in the Top Five biggest importer (CBI, 2017). Furthermore, according to Braungart, one of the founders of the C2C concept, his concept has gained great popularity in the Netherlands and has huge potential in Germany (Poprawa, 2012).

1.3 Research Aim and Research Questions

This research aims to get a better understanding if and to what extent a German or Dutch bamboo product manufacturer can apply the C2C principle 'Nutrients remain Nutrients.' For this research, the term 'manufacturer' refers to a company that either produce the product itself, or brand products sourced from third parties as their own. Therefore, the two terms are used interchangeably (further reasoning can be found in chapter 3.2). As there are no publications that analyse bamboo as a raw material with the C2C principle, this research intends to provide a broad indication of what elements might be relevant for further research. Therefore, this research tries to identify whether there are similarities and differences when it comes to possible challenges and needs with the principle across different industries. The comparison approach used in this research may reveal elements that need special attention as they are concerning multiple industries. Identifying them may provide the opportunity to improve current situations on a larger scale. To conduct the research, the following main research question has been formulated:

> *To what extent can the Cradle to Cradle principle 'Nutrients remain Nutrients' be seen as a viable option for Dutch and German bamboo product manufacturers?*

The following sub-research questions are formulated to support finding and analysing the relevant data for the main research question:

1. *How applicable is the Biosphere to the manufacturers' products?*
2. *How applicable is the Technosphere to the manufacturers' products?*
3. *What similarities and differences can be identified for the manufacturers' challenges and needs with the principle?*
4. *What intentions were present and missing in regards to bamboo and C2C during the design phase?*

1.4 Structure of the Thesis

To present the information logically, this thesis is structured into six different main sections. The first section 'Introduction' provides relevant background information to understand in what context this research can be placed. It further provides the motivation for this research as well as the research aim and the research questions. The second section 'Theoretical Framework' is divided into three different sub-sections. The first sub-section provides information relevant to bamboo, its product variety, its international market, and its circular economy implications. The second sub-section presents the Cradle to Cradle concept, its first principle of 'Nutrients remain Nutrients' in more detail and the concept's

practical implications. The third sub-section presents a conceptual framework this research is using that has been derived from the information found in the previous two sub-sections. The next section of 'Data and Methodology' presents what research methodology has been used as well as how data has been collected and analysed. The fourth section of 'Research Findings' presents information based on the four different industries the products of the manufacturers can be categorised in. Therefore, the sub-sections are divided into consumer items, construction and finishing materials, furniture, and textiles. Afterwards, the section of 'Analysis and Discussion' presents the interpreted information based on the conceptual framework. Therefore, this section is divided into the sub-sections of Material Health, Material Reutilisation, Product of Service, and Design Phase. The section 'Conclusion' presents the key findings of this research. Furthermore, it presents the degree of trustworthiness, the research limitations, and possible further research based on this research.

2 THEORETICAL FRAMEWORK

This section presents the theoretical framework of this research. It will be investigated what academic literature can be found on bamboo in regards to product variety, its international market and its implication on the circular economy. Further, it will be looked at the concept of C2C, its first principle of 'Nutrients remain Nutrients,' as well as its practical implications. Finally, it will be presented a conceptual framework that is based on this literature and will be used as a for conducting this research.

2.1 Bamboo

Bambusoideae, or commonly known as Bamboo, belongs to the grass family and not, as often assumed, to the tree family (Clark et al., 2015). According to the Bamboo Phylogeny Group, Bamboo has about 1,482 species and are categorised into three groups (Clark et al., 2015): the *Arundinarieae* that grows in temperate climate, and higher tropical evaluations, are referred as a woody bamboo; *Bambuseae* that grows in tropical climates and, in rare cases, outside them and is also referred as woody bamboo; and the *Olyreae* that is considered an herbaceous bamboo. Due to its capability to survive on so many different terrains, bamboo is native in Asia, Oceania, Africa, as well as the Americas (Lucas, 2013).

Bamboo's advantageous morphology, which refers to the relationships between structures of living organisms (Oxford Dictionary, n.d.), is shaped by its rhizome system, the stem of the bamboo in the ground, and its culm system that grows above the ground (Chaowana, 2013). Its unique features let bamboo reach its maximum height within 4 to 6 months, by a growth rate of up to 15 to 18 centimetres per day and is able to grow up to 40 to 50 stems in total (Aminuddin, & Abd. Latif, 1991 as cited by Chaowana, 2013). Furthermore, it is able to grow to maturity within 3 to 6 years, which makes it the fastest growing plant of its size (Lee & Perry, 1994; Wong, 1995). Some species may even grow up to 35 metres in height and 35 centimetres in diameter (Kuehl, 2015).

2.1.1 Product Variety

While bamboo has shaped the lives of many cultures, in particular in developing countries where it is native (Lucas, 2013), developed countries in Europe, North America, as well as Japan and Australia became crucial customers for bamboo (Zhu & Jin, 2018). Because of the versatility and the easy processing of bamboo, many different industries are able to use bamboo as raw material and may replace conventional raw materials such as wood, steel, or even plastics (Chaowana, 2013).

The great versatility of bamboo is a result of the ability to use different parts of the grass for different purposes. Van der Lugt and King (2019) presents what parts of the grass can be used for what kind of products. The rhizome and roots are often used for handicrafts and brushes, while the sheaths of the plant are also used for handicrafts, fodder and pulp, while the shoots are solely for food purposes. The base part of the plant can be used for charcoal as well as for handicrafts. The middle-lower part is often used for laminated panels and beams and general flooring, due to its strength. The middle-upper part on the other hand is slightly weaker, but still suitable for curtains, mats, carpets, woven articles and other handicrafts. The top part is mainly used for sticks like toothpicks and skewers, but also for bamboo poles, scaffolding and other agricultural tools. The twigs towards the top are ideal for brooms and textiles. The leaves are often used for manure, fodder, pigments, but also for medicine, juice and other beverages. Looking at the processing waste, it even finds a purpose for particle boards, like charcoal, pulp, granules and even fuels.

As bamboo can be used for so many different purposes, it is possible to categorise the product. Van der Lugt and King (2019) here distinguishes between durable bamboo product, short- and medium-life bamboo products, and products from waste material as presented in Table 1.

Table 1: Bamboo Product Categorisation (van der Lugt & King, 2019)

Product Category	**Products/Industry**
Durable bamboo products	- Bamboo construction and finishing materials (bamboo poles/canes, engineered bamboo for outdoor products, etc.) - Long-life composites (automotive, aerospace, boating, sports equipment, etc.) - Furniture (chairs, tables, etc.)
Short- & medium-life bamboo products	- Consumer items (single bags, cups and cutlery, plates, laptop cases, glasses, kitchen items, health and beauty products, etc.) - Textiles (clothing, etc.) - Paper and pulp (cartons, etc.)
Products from waste materials	- MDF boards - Bio-energy (charcoal, pallets, etc.)

Durable bamboo products are the ones with a lifespan from 5 years up to 25 years, such as bamboo construction and finishing materials, long-fibre composites, and furniture (van der Lugt & King, 2019). Using bamboo as construction or finishing material has various benefits. According to van der Lugt and King (2019), bamboo poles were dominating the market when looking at the traditional construction industry, in particular in Asia. They describe the bamboo

poles length, lightweight, tensile strength, flexibility and its full biodegradability as elements that are highly valued and can be seen as the most rudimentary use of bamboo.

With advancements in technology, the traditional bamboo poles started to share its market with engineered bamboo material that also is categorised as durable bamboo products. This is achieved through different processes that allow producing a flattened, laminated, or compressed bamboo product that has similar properties to conventional wood (van der Lugt and King, 2019). While bamboo poles are suffering from a lack of standardisation, van der Lugt and King (2019) states that engineered bamboo material allows providing standardisation for its stability with properties of having low stiffness and therefore high flexibility. Engineered bamboo panels are ideal for outdoor work, for example for road traffic signs. The fact that laminated bamboos have similar or even higher strength values than its other wooden competitors contributes to this (dos Reis Pereira & Barata, 2014).

Next to the traditional bamboo poles and the engineered bamboo, there are durable bamboo products made from long-fibre composites. According to van der Lugt and King (2019), they are similar to engineered bamboo material, as they are strong and lightweight. Despite the similarities on the first glance, the authors state that long-fibre composite technology is different from the ones for engineered bamboo material, which allows the long-fibre composite to be shaped in various forms through moulding. Long fibre-composites are often used in different industries like the automotive, aerospace, boating, and sports equipment, but also for other industries with construction and even infrastructure purposes (van der Lugt & King, 2019). Another durable bamboo product that should be listed separately, are furniture products. Depending on the design and the production method, furniture can come in a variety of forms and uses (van der Lugt & King, 2019), and can be seen as the most desired product made from bamboo currently within the EU (INBAR, 2019).

Next to the durable products, there are short- and medium-life bamboo products. They are considered having a lifespan of under five years (van der Lugt & King, 2019). Due to the versatile shapes bamboo can be transformed in, it finds application in many different consumer items. According to van der Lugt and King (2019), the products are, but not limited to, single bags, straws, crockery, cups and cutlery, plates, laptop cases, watches, glasses, kitchen items, sports articles, and health and beauty products. Therefore, the authors argue that bamboo has great capabilities of substituting plastic material for these items.

Bamboo can also be used as a raw material for the textile industry, which is also categorised short- and medium-life bamboo products. According to van der Lugt and King (2019), the industry uses the conventional pulping technology to create the desired bamboo viscose that is needed for the spinning process. Generally, Waite and Platts (2009) describe the bamboo manufacturing methods as either being chemically-based or the mechanically-based, resulting in different rates of moisture-wicking and therefore can be used for different purposes (Waite & Platts, 2009).

Another industry that falls into the category of short- and medium-life bamboo products and can benefit from bamboo as a raw material is the paper and pulp industry. It can be seen as an alternative raw material for paper or cardboard manufacturing companies (van der Lugt & King, 2019).

Once a product reached the end of its consumer-phase, the product can also be considered 'waste,' as it has the capability to be returned into the production cycle, resulting into another category by van der Lugt and King (2019). For example, they describe bamboo-based particles boards that often are also referred to as medium-density fibreboard (MDF boards). According to the authors, these boards present opportunities in different industries, from furniture building to paper production. Nevertheless, the authors also state that there is no real distinction on a product level between waste-sourced products or other laminated or engineered bamboo products.

Another way to utilise waste from Bamboo is for bioenergy purposes. According to Sharma et al. (2018), bamboo's biomass can provide a similar amount of energy density as wood or timber. Due to the high similarity, bamboo can be turned into charcoal, pellets as well as gas that then can be used for heating or electricity purposes (van der Lugt & King, 2019).

2.1.2 International Market

Because of bamboo's versatility, it is not only a desired raw material in the countries of origin, but is traded on a global scale. This results in a representation within the international market. Figure 1 presents the major exporters and importers of bamboo and rattan products in 2017.

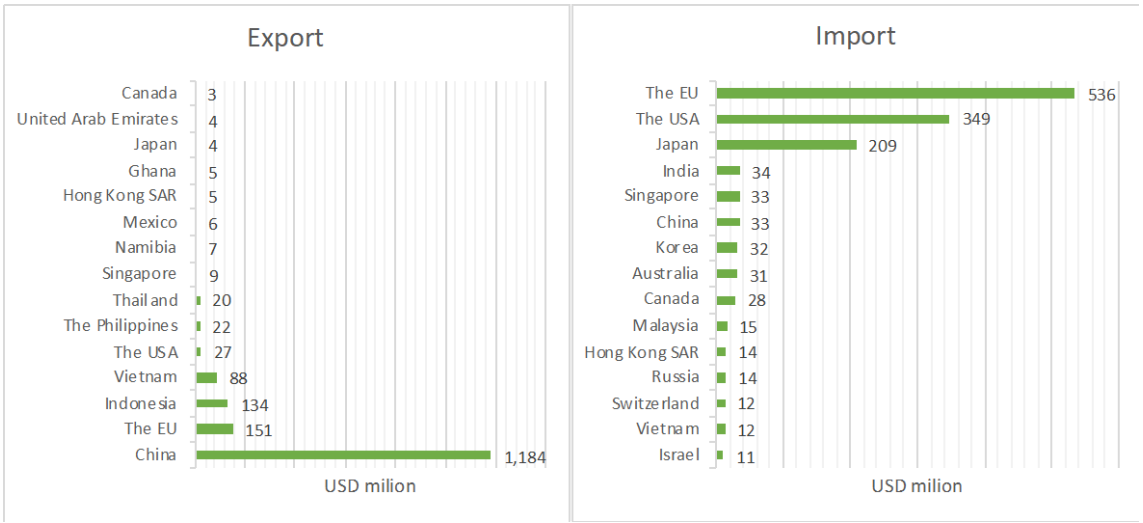

Figure 1: Major Exporters and Importers of Bamboo and Rattan Products in 2017 (INBAR, 2019)

Although INBAR (2019) does not distinguish between bamboo and rattan in figure 1, it is clear that the international market strongly depends on China as

a supplier, as it is by far the biggest exporter with around 71% on the total supply market, followed by the European Union (EU) with around 9%. The import figures show that the EU imports about 39% of the traded bamboo products on the international market, followed by the USA with around 26%. Looking at the figures from 2013 to 2015 that have been analysed by CBI (2017), the market seems not to grow as imports have been stable. However, they looked at the consumption of EU bamboo products, which increased over the three years, indicating a higher demand within the union and resulting in decreasing re-exports of bamboo manufactured products outside the EU. The largest consumers within the EU in 2015 are the Netherlands with €17 million, followed by France with €8 million, United Kingdom with €7 million, and Belgium and Germany with €4 million each (CBI, 2017).

The net importing situation of the EU is not only reflected in the comparison figures shown above but also can be broken down into the different products itself. Figure 2 shows the international trade of bamboo and rattan products in 2017. Here, it is clear that the bamboo and rattan furniture has the highest market share amongst all products, followed by rattan basketwork, bamboo and rattan seats, bamboo raw materials, and bamboo basketwork.

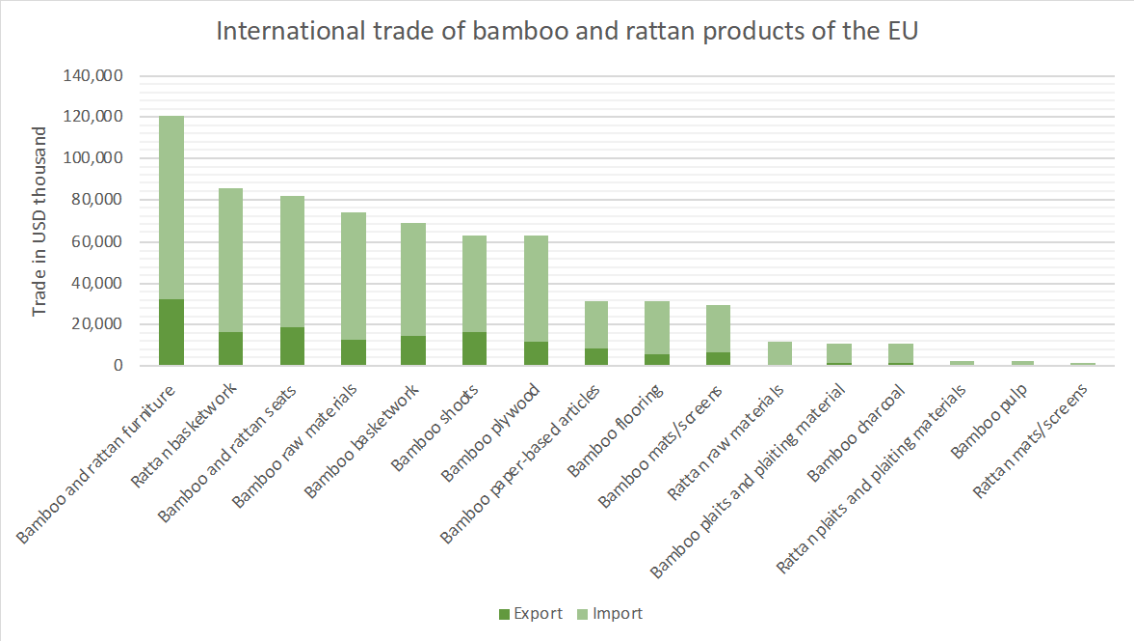

Figure 2: International Trade of Bamboo and Rattan Products in 2017 (INBAR, 2019)

Despite the published distribution, van der Lugt and King (2019) sees difficulties in statistical data for international trade, as they are usually based on the Harmonized System (HS) codes. They argue that there is a lack of HS code standardisation when it comes to bamboo products. They state that in some cases, products may be listed under other HS codes, such as wood products, which creates a skewed statistical picture. Therefore, they claim that the actual trade of bamboo may be higher than represented.

Van der Lugt and King (2019) also present future trends according to their categories. Looking at engineered bamboo as a product, a good indication for potential growth is the wood and building industry in general, those are growing slowly but steadily (ITTO, 2017). In this context, it also needs to be mentioned the general upwards-trend of the green building certifications that is a result of the sustainable transition taking place. According to van der Lugt and King (2019), the good performance of bamboo makes it an attractive building material, which should increase the demand in the upcoming years.

For the same reason for a growing environmental consciousness amongst customers, in addition to the increasing online sale volumes, van der Lugt and King (2019) predicts other categories being affected. They argue that there will be an increasing demand for more sustainable alternatives for consumer items, like cutlery, are also being expected to increase in the upcoming years. Also, the increasing packaging market, accompanied by online shopping, may benefit from bamboo as a raw material for cardboard to meet future demands on more sustainable solutions (van der Lugt & King, 2019).

For the large textile industry, bamboo may have the opportunity to substitute other materials like cotton and polyester (van der Lugt & King, 2019). However, it is expected, due to a rougher texture of bamboo linen, only bamboo rayon has the potential to gain a bigger market share (van der Lugt & King, 2019). Despite that, practices have shown that only a small number of the 1,500 species of bamboo are used for the textile industry, resulting in little knowledge of other potential and better-suited species for manufacturing (Waite & Platts, 2009).

Looking more closely into the reutilisation of bamboo waste in form of particles, the growing wood-based panel market shows an indication that there is potential for the use of it (van der Lugt & King, 2019). As bamboo waste can also be utilised for bioenergy purposes, like in form for pellets, the wood pellet industry that keep growing, thanks to the increased demand for more renewable energy sources, gives also an indication for the potential of bamboo being relevant for this growth (van der Lugt & King, 2019).

2.1.3 Circular Economy Implications

Circular economy (CE) has caught the industries' attention for as a viable concept to increase the aspect of sustainability (INBAR, 2019; van der Lugt & King, 2019). However, the literature provides multiple definitions for CE. These are also a result of different theoretical influences that can be linked to CE. The most common ones are the cradle to cradle, law of ecology, looped and performance economy, regenerative design, industrial ecology, biomimicry, and blue economy (Geissdoerfer et al. 2017). This makes it difficult to pinpoint an exact definition. Nevertheless, Geissdoerfer et al. (2017) looked at different definitions and their mentioned influences that resulted in their own definition for CE. This definition is to be seen ideal, as it does not only address the purpose, but also the actions

needed of how to achieve the purpose. Therefore, this definition is seen as a guiding definition for linking the different elements to CE and is formulated the following:

> *"(…) the Circular Economy [is defined] as a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling."*
>
> *- Geissdoerfer et al. (2017, p. 759)*

With establishing what CE is, it can be identified why bamboo seems to be an ideal raw material for this type of economy. According to INBAR (2019), bamboo has great capabilities for CE thanks to the renewable element. It is stated that its morphology allows it to regenerate itself quickly, survives harvesting with ease, grows on soil that is not ideal for farming, and enables to regenerate soil by raising the water table. INBAR (2019) also sees bamboo as highly resource-efficient, as it is possible to utilise 100% of the plant.

Additionally, they see bamboo as an ideal material that can be recycled. The ability to use bamboo waste for new products as well as its biodegradability makes it an ideal raw material for single-use products that currently rely on plastics as a raw material (INBAR, 2019). It is also stated that bamboo waste can be used for bio-energy production thanks to its natural and regenerative origin. However, waste within CE like for energy generation is considered 'leakage' and should be minimised as much as possible or even avoided (van der Lugt & King, 2019; McDonough & Braungart, 2002).

Another aspect that is advantageous for CE is the low carbon footprint bamboo can have (INBAR, 2019). Its ability to act as a carbon sink, which refers to the plant's capability to store carbon, allows it to have a lower carbon footprint as the other materials like steel or cement. One study by van der Lugt and Vogtländer (2015) even shows that industrial bamboo materials are capable to have negative carbon emissions, meaning it is capable to store more carbon than it emits throughout its life cycle.

The last aspect mentioned is referring to bamboo's property of being durable. According to INBAR (2019), this is in particular interesting for the construction industry, as this industry has one of the highest carbon footprints due to relying on abiotic materials to ensure durability. The study of van der Lugt and Vogtländer (2015) even revealed that the eco-costs of bamboo are lower than the ones of hardwood that is commonly used when durability is needed.

Looking at these different CE aspects stated by INBAR (2019), it can be said that many are reflected in the definition set by Geissdoerfer et al. (2017). However, despite the clear advantages of bamboo, van der Lugt and King (2019)

saw the need to set criteria for the 'perfect' bamboo product for CE. They propose that the product needs to:

- have a lifespan long enough to enable the resources to grow back;
- be able to substitute abiotic materials;
- have 100% bio-based content;
- be reusable over multiple product cycles; and
- at the end of its use, be biodegradable or otherwise safe to burn for energy production.

While bamboo is able to outperform other materials in terms of sustainability, it still may not be able to meet the criteria for CE, due to current practices and technological accessibility (van der Lugt & King, 2019). For example, although bamboo poles are inherently ideal for single-storey houses as their environmental impacts are the lowest in comparison to brick and concrete materials (Escamilla et al., 2018), the biodegradability often requires treatment with artificial preservatives or lacquers for preservation and visual appeal, hinders the biodegrading process, leading to difficulties of applying the CE concept entirely (van der Lugt & King, 2019).

Looking at engineered bamboo products and long-fibre composites, they require the use of resins, laminates or other synthetic glues (van der Lugt & King, 2019). However, despite this, the environmental performance of engineered bamboo in comparison to traditional construction materials like brick or concrete is still higher and therefore should be favourable for multi-storey buildings looking from an environmental perspective (Escamilla et al., 2018). A study in Nigeria revealed not only the great potential of replacing conventional construction materials with locally grown bamboo but also revealed the environmental benefits of fostering bamboo as a viable alternative (Atanda, 2015). However, it needs to mention that current practices within the construction industry are dominated by recycling as a waste management tool, rather than applying a design that allows disassembly and reuse for different purposes which is a preferred way of letting materials flow back into the stream from a CE point of view (Cruz Rios et al., 2019).

The applicability of CE for furniture depends on multiple factors. While furniture can be treated with lacquers or are formed with other synthetic adhesives to achieve the desired shape of the furniture, it can also be produced in a fully biodegradable way and therefore comply to the CE idea entirely, which however depends on the how easy it is to disassemble the furniture and what bamboo material is used (van der Lugt & King, 2019). Additionally, using bamboo as a raw material for wood furniture manufacturing machines achieves good performances in comparison to traditional wood (Shi & Wang, 2013).

Similar to furniture, consumer items, are dependent on the material used. According to van der Lugt and King (2019), the industries often rely on synthetic materials and chemicals such as melamine that makes the product more heat resistant and therefore more durable. They claim that this permanent fusion leads

to the inability to recycle the products, resulting in a non-applicability to the CE approach.

Issues also arise in using bamboo in the textile industry. Van der Lugt and King (2019) state that bamboo fibres are considered relatively tough, resulting in a greater need for chemical volumes in comparison to other raw materials when using pulp technology. They even concluded that the environmental performance of bamboo textiles can be lower from a life-cycle perspective than for recycled or softwood-based pulps. Despite the negative performance of current practices, technology is developing in this field of production processes with the help of nanotechnology as well as more eco-friendly solvents (van der Lugt & King, 2019).

Similar limitations are also within the paper and pulp industry. Van der Lugt and King (2019) see the products themselves as fully biodegradable if not coated with plastics for water resistance. However, they recognise that most current practices either produce harmful by-products, such as black liquor or require harmful chemicals like chlorine. Although current practices cannot be seen as fitting with the CE concept yet, the authors still see high potential in this industry as there are prospects of cleaner bleaching technologies in the future that could make a big difference in terms of circularity.

Repurposing waste into new products, like MDF boards, also imposes issues as the high content of synthetic resins and other synthetic additives needed, fail to meet the idea of CE (van der Lugt & King, 2019). However, looking solely on the sustainable performance, MDF boards have a better performance, but only on a local level, in most cases where bamboo is native, and therefore cannot compete with recycled European softwood in Europe (Vogtländer et al., 2010).

Utilising bamboo for energy purposes, from a sustainable perspective, the faster regenerative ability of bamboo seems to make bamboo more favourable over other woods used (Vogtländer et al., 2010). Nevertheless, from a CE perspective, creating energy by burning bamboo is considered 'leakage' and should be avoided if possible (van der Lugt & King, 2019).

Overall, looking at the current conditions within the bamboo industry overall, improvements could be made. For that, van der Lugt and King (2019) presented five recommendations to foster a circular and bio-based economy for bamboo. As many products currently rely on synthetic additives and require other chemicals for processing purposes, they see the need for essential changes in this field. Therefore, their first recommendation addresses to conduct further research in these areas and find bio-based alternatives.

The second recommendation by van der Lugt and King (2019), addresses how information is handled. Manufactures should be transparent about the content of the products towards the consumer and should set themselves development goals that should help them to get close to a 100% bio-based product.

The third recommendation by van der Lugt and King (2019) proposes the development of an integrated bamboo industry. To achieve that, it needs to make sure to focus lies on the sustainability aspect of all elements involved with bam-

boo, including legislative conditions, despite the huge potential to build an industry quickly due to bamboo's fast growth rate. Furthermore, all the different species of bamboo should be utilised, as each species offers different opportunities for different products. Additionally, a value chain analysis should be conducted when a company is interested in using bamboo as a raw material. Knowledge transfer as well as best practices are also seen as a crucial element to develop an integrated bamboo industry. Once these elements are given and provided, it is possible to develop sub-industries within the industry that support each other by using different parts of the bamboo. However, they point out that aiming too high from the beginning may work against the cause, and a gradual improvement is recommended.

The fourth recommendation made by van der Lugt and King (2019) is taking advantage of climate crediting possibilities. As bamboo acts as a carbon sink, including bamboo in various schemes, standards, and methodologies, addressing climate change measurements and management helps to foster bamboo plantations and forests on a global scale.

The last recommendation made by van der Lugt and King (2019) is addressing the lack of accurate integration of bamboo in the Harmonized System (HS) classification. HS codes help to give a better picture of the growth and distribution of bamboo on the global market. The current HS classification forces some products to be listed in HS codes for different products such as wood or textile. With having more accurate international trade data, it is easier to incentivise investments and provide more fitting legislations.

2.2 Cradle to Cradle

According to Geissdoerfer et al. (2017), Cradle to Cradle (C2C) is one of the most common theoretical frameworks influencing the CE concept. C2C is a registered trademark and has been developed by architect and designer William McDonough and chemical scientist Professor Dr. Michael Braungart (Luther, 2012). They have first described this theoretical framework in their book ***Cradle to Cradle: Remaking the Way We Make Things***. C2C is inspired by nature and should be seen as an approach for continuous improvement design that does not necessarily have the aim of reducing the negative ecological footprint through efficiency, but to create a positive footprint through effectiveness (Braungart, 2018; Minkov et al., 2018). According to Braungart (2018), climate neutrality can only be achieved by not existing, which is unrealistic. He states that *"(…) the approach to Cradle to Cradle is not to minimise the Ecological Footprint, but to maximize it – but in such a way that it creates a wetland full of wildlife"* (Braungart, 2018).

In order to maximise the positive ecological footprint, C2C is based on three principle ideas (McDonough & Braungart, 2002; Minkov et al., 2018): waste equals food; use current solar income; and celebrate diversity. The C2C consulting firm Environmental Protection Encouragement Agency (EPEA), led by co-

founder and CEO Braungart, published an updated formulation of the principle ideas on their website (EPEA, n.d.-a): nutrients remain nutrients; use of renewable energy; and support diversity. While in essence and the underlying idea is the same, it may seem to be modernised after their first formulation 18 years ago in 2002. The idea of the principles can be summarised as the following (EPEA, n.d.-a; McDonough & Braungart, 2002; Minkov et al., 2018):

1. Nutrients remain nutrients: Waste needs to be seen as nutrients that allows to nourish other organisms, meaning it requires a product design that makes it safe for human health and the environment, with being beneficial during all product phases.
2. Use of renewable energy: Energy consumption needs to be sourced by renewable energy such as solar, wind, hydroelectric, geothermal, and biomass energy in order to ensure an effective design of the product.
3. Support diversity: It is essential to provide social fairness and stakeholder considerations; hence the ideal solution requires the adaptation to biological, cultural, social, and conceptual circumstances, meaning a 'one-size-fits-all design' is not appropriate.

Looking at principles of other system theories those influence CE, there is great overlap with principles of C2C (van Dijk et al., 2014), meaning C2C addresses the most crucial elements in this field. However, looking more closely at the C2C philosophy itself, the most applicable principle is the first principle of 'Nutrients remain Nutrients' (Toxopeus et al., 2015), resulting in the focus of this principle for this research.

2.2.1 Principle 'Nutrients remain Nutrients'

McDonough and Braungart (2002) describe today's consumption norm as one relying on throwaway products. Their first principle 'Nutrients remain Nutrients' is intended to address this unhealthy norm of waste generation and provides a better approach on these practices. They propose that a product needs to be designed from the very beginning in such a way that it is assumed that no waste exists. To help with that, they used the idea of metabolisms and translated that into a supply chain context. Metabolism is defined as a *"chemical and physical processes by which a living thing uses food for energy and growth"* (Cambridge Dictionary, n.d.). With this look at nature, McDonough and Braungart (2002) developed two different metabolic cycles for the business world, as to be seen in Figure 3.

The first metabolic cycle is the biological cycle, or also called Biosphere. According to McDonough and Braungart (2002), and further described by Toxopeus et al. (2015), the Biosphere should contain all the relevant products that can be seen for consumption, meaning products that are exposed to heavy abrasion and deterioration during the use phase. They state that these products, therefore, require being based on renewable sources only to provide the biological nutrients to the organisms. Designing the product for the Biosphere in mind allows

the business to not only to disregard conventional measure like reducing, reusing, or recycling products to cope with environmental issues, but also to neglect environmental regulations (McDonough & Braungart, 2002).

Within the Biosphere, as presented in Figure 3, there are two ways to return the nutrients. The first way is a regeneration by industrial processes (b1). The second way is through a regeneration by the natural environment again (b2). At the end of both methods, it is possible to harvest a bio-based resource.

The second metabolic cycle is the technical cycle, or also called Technosphere. As described by McDonough and Braungart (2002) and Toxopeus et al. (2015), it encompasses products that do not wear off during the use phase and should be designed in such a way that its materials (referred to as technical nutrients) are remaining in the Technosphere for other products. To be able to let the product circulate in the Technosphere, McDonough and Braungart (2002) emphasised the importance of designing the product in such a way that it can be disassembled. They are also often referred as service products.

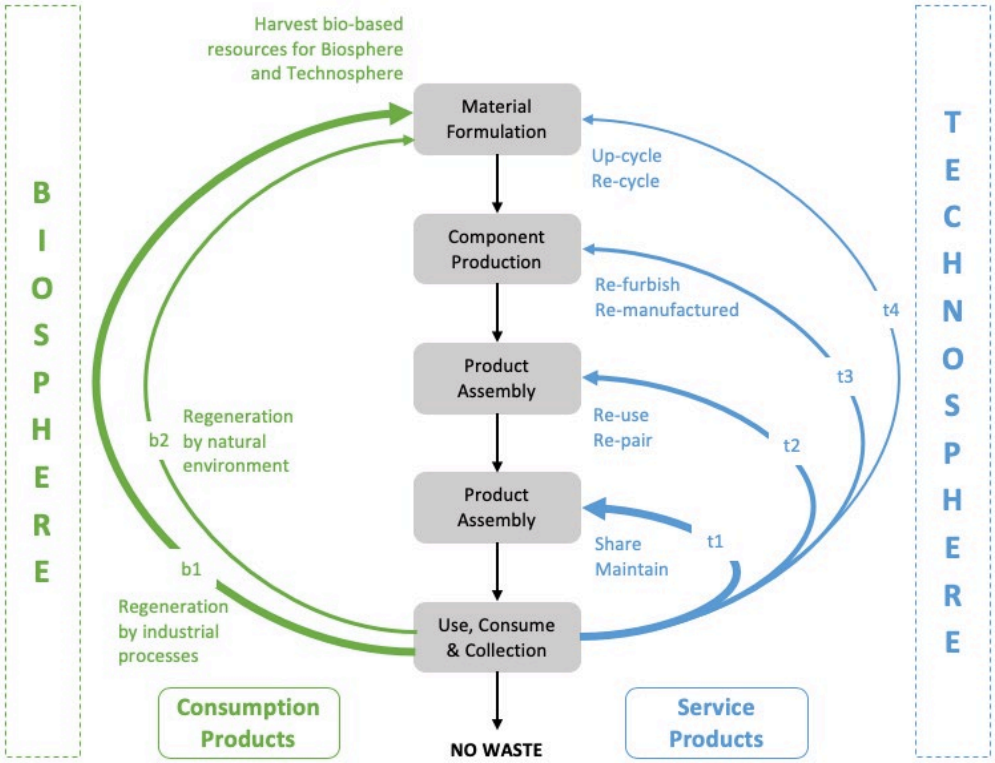

Figure 3: Metabolic Cycles of C2C (EPEA, n.d.-b)

Within the Technosphere, there are four different way to bring the technical nutrients back to the cycle (see Figure 3). It is possible to return them by sharing the product with others or maintaining the product to keep it in good shape and therefore extending its lifespan (t1). The second way (t2) to bring the valuable materials back into the cycle is to re-use them, meaning using the product more than once (Cambridge Dictionary, n.d.), and re-pair the product, mean-

ing to make the damaged, broken, or the incorrect working product in good condition again (Cambridge Dictionary, n.d.). Another way to return the technical nutrients is to re-furbish and re-manufacture the product (t3). While, refurbishing refers to products that have been solely repaired, tested, and verified by the manufacturer and are resold afterwards, remanufacturing is more cost-intensive as the product will be rebuilt with the help of reused, repaired and new parts (Vecmar, 2018). The last option that should be taken are the up-cycle and re-cycle options (t4). The main difference between re-cycling and up-cycling is that re-cycling is the process of turning waste into products or materials that can be used in the manufacturing process again, and up-cycling focuses on turning the waste into a product or material that is of higher quality than before by repurposing it (Gunther, 2019).

In addition to the different cycles of the Technosphere, McDonough and Braungart (2002) propose the concept of Product of Service (PoS) or Eco-Leasing for this sphere. The authors try to address with this concept the loss of materials during the purchase of the product. This concept proposes that the product remains in the ownership of the manufacturer and the manufacturer only sells the service or function of the product for a contracted period of time. The authors argue that this way the materials remain in the company's material loop, saving billions of dollars in materials over a longer period of time, and may give the option to resell a service by offering upgrades to better products, creating a better buyer-customer relationship. Next to these benefits it is also argued that it creates huge environmental benefits as it will be in the manufacturer's interest to produce the most effective products when implementing this concept.

In some cases, neither of the Biosphere or Technosphere can be applied to the used materials. McDonough and Braungart (2002) here refers to products that are designed in such a way that fuses biological and technical materials. These products nutrients then cannot be recovered, leading to losing them to landfills or incinerators. The authors call them monstrous hybrids. Furthermore, they present the term unmarketables, which refers to materials those do not fit into either one of the metabolic cycles, as they are considered hazardous. They state that these materials require special care until there are ways discovered to detoxify them.

To ensure of compliance to the C2C concept and communicating this compliance to stakeholders, it is possible to get certified on C2C and use it as an environmental management system (Ünal & Shao, 2019). The certification helps to provide a context and framework for the involved parties (Luther, 2012). For this, the certification will look at five different categories: Material Health, Material Reutilisation, Renewable Energy, Water Stewardship, and Social Fairness (MBDC, 2016 as cited by Ünal & Shao, 2019). Van Dijk et al. (2014) associates the categories Material Health and Material Reutilisation with the first principle of C2C 'Nutrients remain Nutrients.' Although he recognises that water stewardship can be associated with it also, he points out that the used materials during the production itself determine the water quality, resulting in no need of consideration for this principle. On the one hand, the category of material health looks

at what materials have been used during the manufacturing process (van Dijk et al., 2014). For C2C practices, that means that materials should be used that are optimised for the each one of the metabolic cycles and try to avoid materials and chemicals that are either considered X and Grey within the ABC-X assessment chemical hazard profiling method, or ones that are listed as banned materials from the certification programme itself (MBDC, 2016 as cited by Ünal & Shao, 2019). On the other hand, the category of material reutilisation deals with material recovery and therefore with the described metabolic cycles, identifying the degree of compliance in percentage within each cycle resulting in a score and therefore determining the level of the category of the certification (MBDC, 2016 as cited by Ünal & Shao, 2019).

2.2.2 Practical Implications

As C2C has been published a while ago already, the concept has found some application in some countries more than others. According to McDonough and Braungart (2009), C2C is to be seen as a supportive strategy, which is the reason why the concept gained great popularity in the Netherlands. They describe the Dutch being influenced by their geographical location, resulting in a culture that is heavily based on support within the community in order to survive on land that is below sea level. At the same time, Braungart states that the Dutch look closely at nature to take advantage of its mechanisms by seeing nature as a partner and teacher, which also leads to a higher receptiveness to the C2C approach (Poprawa, 2012; Schnettler, 2019). Moreover, he sees its home country Germany, and neighbour of the Netherlands, having a problem with breaking through the linear thinking (Poprawa, 2012). Nevertheless, he sees first great developments and believes Germany can become one of the forerunners once the concept and its benefits are understood (Poprawa, 2012).

The applicability of C2C can also be looked at on a micro-level of organisations. Firstly, C2C is said to be more appealing for small- and medium-sized enterprises (SME), as it requires far less expert knowledge and financial resources in comparison to a Life-Cycle Assessment (LCA), which tends to be more complex in the analysis part (Bjørn & Hauschild, 2013). Secondly, the certification process of C2C raises some critique. Toxopeus et al. (2015) argue that the lack of publicly available information on how the ABC-X score is formed with the database used raises the concern of practices that depend on the interpretation by each individual institute. In this context, they also argue that, due to the speciality of the employees of Environmental Protection Encouragement Agency (EPEA) and McDonough Braungart Design Chemistry (MBDC), the main assessment focus lies within the material assessment and internal procedures rather than fostering innovation. The aim of C2C being eco-effective requires open innovation and interdisciplinary cooperation, which, however is also not possible thanks to signed Non-Disclosure Agreements of the accredited institutes with the companies (Toxopeus et al., 2015). Thirdly, the focus of C2C mainly lies in technical

solutions and misses out on solutions that can develop from societies and cultures (Reijnders, 2008).

Looking specifically at the different spheres of C2C, some critique has been stated. On the one hand, there is the idea of biological nutrients. An increase of biodegradable materials in the environment can have negative effects on the eutrophication as there is a limit of absorbance (Reijnders, 2008). Furthermore, the complexity of ecological systems resulting in the fact that certain natural material is hazardous to some organisms, and fertilising the ground to higher levels than normal may give certain species an advantage over others, leading to a decrease of biodiversity (Rusek, 1993); Norton et al., 2006). On the other hand, there is the idea of technical nutrients. Reay (2011) criticises the idea of a closed-loop, which fails to mention the wearing out process during the use phase. Furthermore, the idea of reusing synthetic materials is limited and the concept of maintaining a product made from synthetics or metals is in practice not realisable in some cases (Reay, 2011).

Another aspect that is often addressed is the comparison between an LCA and C2C. However, it is said that LCA, with its focus on eco-efficiency, and C2C, with its eco-effectiveness, complement each other greatly (Bjørn & Hauschild, 2013; Bakker et al., 2010). The advantage of C2C, according to Bjørn and Hauschild (2013), is the ability to communicate positive attributes of the product in terms of environmental, economic, and social aspects, while the LCA solely focuses on negative environmental impact reductions. The authors describe that in practice there is no conflict between conserving material resources and increasing eco-efficiency. However, in some cases, there is a trade-off between the energy used and the materials used, in which case energy consumption and its environmental impacts should be considerable elements (Bjørn & Hauschild, 2013).

Another important practical implication of C2C refers to the emphasis on the design phase (McDonough & Braungart, 2002). Design often has to deal with trade-offs caused by criteria such as costs or performance (Nielsen & Brunoe, 2015). Applying C2C within the design phase is therefore strongly determined on a strategic management level and cannot be only applied by skilled designers (Bakker et al., 2010). Also, there is a perceived dogmatism of the design element that C2C in its entirety is applicable to all designs at any time (Bakker et al., 2010).

Next to critique on the implication of C2C in the design phase, there is some lack of consideration when it comes to current waste- and energy infrastructure (Bjørn & Hauschild, 2013). Nielsen and Brunoe (2015) also address in this context issues with the logistical infrastructure of the manufacturing process. They argue that using reclaimed products at the end of their useful life-cycle makes it difficult to forecast when they return, leading to more difficulties in planning and scheduling the manufacturing process. They further argue that such a business model may become an issue for products with a long life-cycles in acquisitions and merging negotiations as well as company closures.

2.3 Conceptual Framework

Based on the previously presented research and theories, a conceptual framework, as to be seen in Figure 4, has been created in order to help with conducting this particular research. For this, manufacturers of bamboo products, producing products that can be either categorised as durable, medium lifespan or short-term lifespan, are considered. Each one of them will be looked into in order to see how applicable the proposed metabolic cycles of C2C are. The applicability of the metabolic cycles can be seen to be influenced by two elements. First, the manufacturers' capabilities for implementing the respective elements are seen as influential. Second, the design consideration that the manufacturers apply to the product, based on certain intentions, is seen as a vital factor for the applicability for this concept. Based on these two elements, it is investigated how applicable the Biosphere and the Technosphere are.

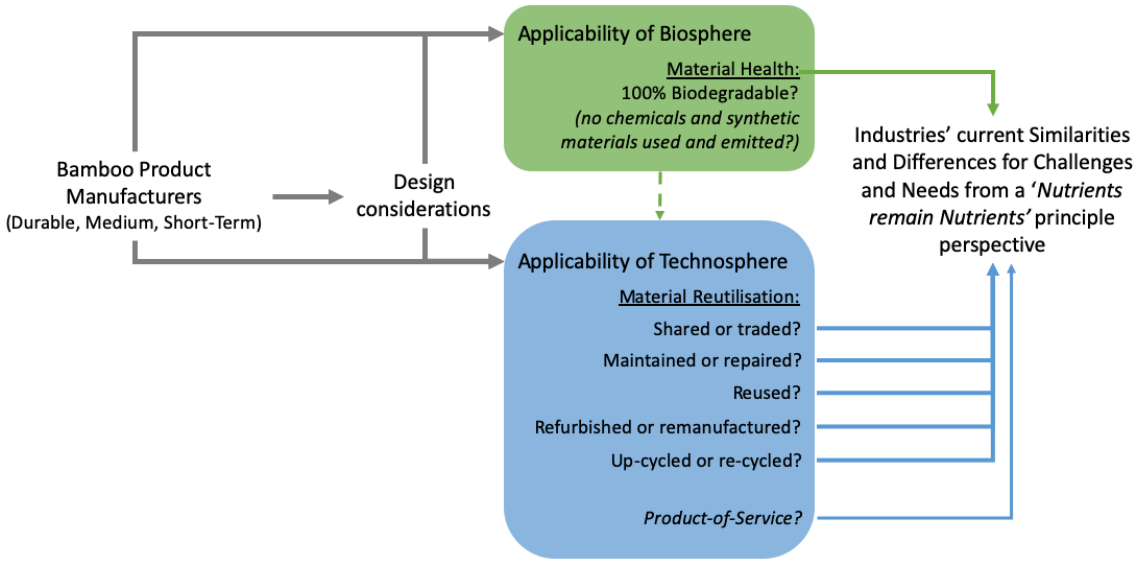

Figure 4: Conceptual Framework for this Research

For the Biosphere, it will solely be looked from the Material Health perspective. As an assessment for the original certification criteria of Material Health exceeds this research scope, it requires generalisation. Therefore, it will be looked into whether the product is 100% biodegradable or not, so it can be seen as a pure consumption product. Being 100% biodegradable for this research assumes the avoidance of synthetic materials and other harmful chemicals used for the product itself or are emitted during the production process. Emissions created from any kind of transportation and energy production are excluded as they are related to the second principle of C2C. Furthermore, how a product that may be categorised as 100% biodegradable is returning its biological nutrients into the cycle, is not looked into. For this research, it is only relevant whether on a practical level, it is feasible to manufacture a product that upholds the C2C standards

of biodegradability, as there has been general limitations stated in the literature in regards to the feasibility of the biodegradability. It is assumed that the biological nutrients are preserved through the current infrastructure.

For the Technosphere, it will be looked into the Material Reutilisation for this metabolic cycle only. The outcome of the Material Health element of the Biosphere indirectly covers a Material Health assessment for the Technosphere also, which leads to the exclusion of it here. The outcome may signalise the need for a Material Reutilisation within the Technosphere as it may not fulfil the criteria for the Biosphere. However, the actual assessment criteria as they are used for certification purposes for the Material Reutilisation category are not used as they exceed the research scope. Therefore, only the general material recovery options proposed in C2C, provide a picture of whether a reutilisation of the manufacturers' products is feasible or not. With that in mind, it will be looked into each material stream individually. The first one here addresses whether the product is either shared or traded amongst customers. The second one addresses to what extent the manufacturer offers maintenance and repair options to the customer. Also, it will be looked into whether the actual product can be reused in its original form for the same or different purposes. The next stream addresses the refurbishments and remanufacturing options that manufacturers have and utilise. The last stream is addressing the ability to recycle or even upcycle the product. Additionally, although not entirely related to the physical material streams themselves, the PoS concept is addressed. According to C2C, the PoS's resulting business model is a vital element for the material recovery and the effectiveness of the products. Therefore, manufactures are asked on their take on this concept in the context of their business and their products.

Finally, because the literature provides similarities and differences when it comes to bamboo's limits within CE, it will be assumed that there are current similarities and differences for challenges and needs when considering applying the principle 'Nutrients remain Nutrients' for the industries. With that, it is investigated to what extent this principle is seen as a viable option for the participating manufacturers.

3 DATA AND METHODOLOGY

This chapter describes how the research has been conducted. To assist with the process, the research onion by Saunders et al. (2009a) has been used, as it addresses different methodological elements and is seen as a common tool for business-related researches and studies like this one. Therefore, it is first described what research methodology has been applied to set the frame for this research. After that, it is described what the data collection entailed and how it has been executed. Finally, it is described how the collected data has been analysed.

3.1 Research Methodology

The first layer of the research onion is the research philosophy. One of these philosophies is the stance of pragmatism. According to Saunders et al. (2009a), this implies that the nature of reality and being is to be seen as complex and external, and is determined by processes, experiences and practices. Furthermore, the authors state that this belief system requires for 'true' theories, which is bound to being able to act successfully and that practicality is in the focus. Additionally, the stance of pragmatism sets the researchers values as important, as it is the researchers' responsibility to interpret the results, meaning it needs to apply an approach that allows viewing the data objectively as well as a subjectively (Saunders et al., 2009b). Looking from the perspective of this research, the stance of pragmatism is seen as the best suitable one. C2C is an external tool that deals with complex situations resulting in the need for experiences as well as specific practices and processes. Also, as this research relies on qualitative data that may or may not refer to quantitative information to back up the reasoning for forming certain opinions, and the general nature of the investigated fields dealing with matters of quantitative basis, being able to accept both, the collected qualitative data and recognise the quantitative data the collected qualitative data may refer to as truth, may be seen as an important philosophical stance for this research.

Looking at the different research approaches, Saunders et al. (2009b) describe three different options: deduction, induction, and abduction. While the deductive approach is testing an existing theory found in literature and the inductive approach is intending to explore a phenomenon leading to create new or build upon existing theory, the abductive approach combines the deductive and inductive approaches, meaning it first allocates a phenomenon by collecting and analysing data that then will be put to the test with additional data collection (Saunders et al., 2009b). Although the philosophy of pragmatism often applies an abductive approach (Kaushik et al., 2019), the scope of this research does not allow testing the identified phenomenon, patterns or themes. The aim of this research is only to identify the similarities and differences of the challenges and

needs with the C2C principle. Therefore, the inductive approach is applied, as it solely looks into what phenomenon, patterns, or themes can be found in the collected data.

Although the research design is not explicitly referred to as one of the research onion's layers (Saunders et al., 2009b), its determination is still seen as relevant. One of the designs is an exploratory research design. According to Hair et al. (2016), the usage of an exploratory research design is appropriate when the researcher has only little previous knowledge about the topic in regards to the research problem or any opportunities linked to the topic. Therefore, the authors describe this design as an ideal design when the aim is to discover something new like relationships, patterns, themes, or ideas, that cannot be prior by formulated into hypotheses. As for this particular research, it has to rely on a very limited to non-existing previous published studies exploring C2Cin a bamboo context. Formulating a hypothesis is therefore not applicable. Therefore, this research applies an exploratory research design as it enables to provide a generic overview of possible challenges and opportunities in this field. It may be even be seen as a foundation for further research that looks into C2C and bamboo as resource material.

One of the research strategies that can be applied is the case study approach. According to Morris and Wood (as cited by Saunders et al., 2009a), this strategy is ideal if the aim is gaining general knowledge of the research context as well as when processes are being implemented. Furthermore, it is a common technique for exploratory studies and when there is a focus on specific firm or industry (Hair et al., 2016; Saunders et al., 2009b). As C2C can be seen as a process or tool to be implemented, and there is a special focus on firms and industries, this research strategy is applied.

Another layer of the research onion is the research choice. According to Saunders et al. (2009a), making a decision on the research choice is determined whether the data collection and the data analysis is quantitative or qualitative. While they describe quantitative data collection and -analysis as producing mainly numerical data, such as from questionnaires and in form of statistics, qualitative data collection and -analysis produce non-numerical data, such as from transcription and in form of data categorisation. Choosing one over the other depends on the intention of the research. A qualitative approach is aimed at interpretation and understanding, while a quantitative approach is aimed at explaining, testing hypothesis, and producing statistical analysis (Eriksson & Kovalainen, 2008). With that in mind, Saunders et al. (2009a) further describe different choices a researcher can make, depending on the combination of the data collected. One of the choices is referred to as multi-method qualitative research. Here, qualitative data is being collected in multiple ways (Saunders et al., 2009a). Looking at this particular research, a multi-method qualitative research is applied. The reason for this lies in the nature of this particular research. First, the lack of research done in this field does not allow to produce a hypothesis that can be tested. Therefore, interpreting and understanding the manufacturer's statements is needed. Second, the research relies on the voluntary participation of the

manufacturers. To increase the convenience for the manufacturer and therefore the likelihood to increase the participation rate with it, offering different data collection methods to the manufacturers is seen beneficial and not seen as a loss.

The time horizon is another layer of research onion. One of the time horizons, that is commonly used for case studies and qualitative data from interviews is the snapshot (also referred to as cross-sectional study), which captures solely a specific pre-determined moment in time (Saunders et al., 2009a). As this research is looking to investigate what is the viability of the C2C principle with bamboo today, a cross-sectional study approach is applied.

3.2 Data Collection

Together with the data analysis, the data collection is one of the last elements of the research onion by Saunders et al. (2009a). The data collection is split into the secondary and primary data collection (Hair et al., 2016). Secondary data for this research relies on external data, such as scientific publications or reports from credible sources, as this research is not executed in collaboration with an organisation that is able to provide internal data. For the primary data, it is aimed to collect internal data that allows getting a better understanding of the research topic.

To collect data, it has been decided to use interviews. According to Hair et al. (2016), interviews are seen as a good option when dealing with sensitive or complex information as well as when the research relies on open-end questions. Because it is intended to collect internal data that may refer to complex and sensitive information, the method of interviews is seen as ideal. The interview type that will be applied for this research is a semistructured interview. This type allows the researcher to explore further unexpected answers through follow-up questions that were not initially planned (Hair et al., 2016). Having the flexibility to either rephrase questions or ask additional questions for clarification purposes, can be a good approach to handling the complexity and sensitivity that this research deals with. Although focus groups are popular for semistructured interviews (Hair et al., 2016), it has been decided against this approach as it is seen as impossible to gather all interviewees at the same time to the same place. Furthermore, this research may require individuality towards the interviewee, where the research needs to go into detail that may or may not be appropriate for the other interviewees present. Therefore, interviews are conducted individually, which is also referred to as a one-to-one approach (Saunders et al., 2009b). Although unstructured interviews may also allow for in-depth exploration (Hair et al., 2016), this research needs to cover specific elements of C2C that seems best investigated through a semi-structured approach.

Because it was decided on keeping the data collection as flexible, convenient and cheap as possible for the participant, as this research is based on the willingness to help of the companies, the participants had the option to answer

the interview questions in a personal talk, like a phone, video conference call, or a personal talk face-to-face by an on-site visit, or answering the questions in written form. Although the traditional way of interviewing is to be seen as a face-to-face meeting or a personal talk on a phone, answering interview questions written form can also constitute as an interview (Meho, 2006).

For the personal talks, it was tried to schedule a meeting to allow preparation for the company itself thinking about the topic as well as the ability to organise a quiet interview environment for the interviewer and interviewee. For the video calls, the providers GoogleMeet and Zoom have been used. If the premises of the interviewee are located near the interviewer (about 150km radius), and the interviewee was willing to have a meeting face-to-face, a site visit was also done. The advantage of conducting the interviews in a personal talk is that it allows responding immediately to the topics raised and allows to react to it, like with follow-up questions (Hair et al., 2016). In order to analyse the interviews better, the interview, with an agreement of the interviewee, has been recorded with the app Recordium and/or QuickTime from Apple. The interview questions themselves can be seen in Appendix 1 and 2, which, however, may have been tailored slightly to the company's industry and products. Possible follow-up questions after the scheduled interview, also with the agreement of the interviewee, has been done via e-mail.

If a participant wished to answer the questions in written form, the approach of e-mail interviewing has been applied by establishing a dialogue through e-mail correspondence. According to Meho (2006), this way of interviewing allows the interviewee to take its time to read the questions and formulate his/her answers. He also states that the response time might end up being longer. Furthermore, Meho (2006) argues that stating the interview questions within the actual sent e-mail is the most effective way in comparison to attaching a document to the email, where the interview questions are stated. He reasons this argument with the fact that interviewees can grasp the questions quicker and it avoids technical issues with opening the document with extra software. However, for this research, it was decided to work with an external attached Word document to the email. The first reason for doing so is that some of the open interview questions are resulting from Yes- or No-answers. Ticking a box in a Word document allows a better understanding of the structure of the interview questions. Furthermore, some sections of the interview require introductory sentences, that are seen to be best given in a clean outline. For providing a clean outline and avoiding deleting questions or introductory sentences accidentally, it was decided to lock all text within the document and only allow the respondent to type in his/her answers in designated text-fields. Once the respondent finished the interview questions, it was sent back to the interviewer via e-mail. The external documents of the interview questions in English and German can be found in Appendix 1 and 2. These drafts then may have been tailored to the company's industry and products. Depending on whether the interviewee allowed follow-up questions, this was done the traditional way in an email without external documents.

Next to determining what kind of data collection is used, it is important to look at the sampling process, which is presented by Hair et al. (2016). Here, the target population needs to be determined, which is presented in Table 2. It will be focused on any small and medium-sized enterprise (SME) manufacturing and/or branding bamboo products under its name. As the European bamboo market heavily relies on imports from Asia (INBAR, 2019), and consequently some European companies rely on expertise and manufacturing in other countries, this research will also include companies that may have outsourced their production. The main criteria here is that the company markets the product under their brand. The focus on SME has been based on the fact that that C2C is seen as ideal for SMEs (Bjørn & Hauschild, 2013). Because of the high demand for bamboo in the Netherlands and Germany (CBI, 2017) and the great popularity and opportunities of C2C in the Netherlands (NL) and Germany (DE) respectively (Poprawa, 2012), the companies should have their headquarter located in one of the countries. Only companies that have bamboo products in their portfolio at the date of the interview will be included, as this research tries to provide the most recent snapshot. Furthermore, as this research is using a qualitative method, the sampling method is a non-probability sampling. The type of sampling method will be a judgement sampling. According to Hair et al. (2016), for this specific type, the researcher is using its judgement for determining what elements represent the target population. The authors also refer this type of sampling as a type of convenience sampling, which allows the collection of data based on its availability. Because data collection for this research can be seen difficult due to its internality and therefore sensitivity, getting hands on any data gathered is to be seen as acceptable data.

Table 2: Target Population

Element	Small and medium-sized enterprises (SME) producing or branding bamboo products under their name in the industries of construction and finishing materials, furniture, consumer items, textile, and paper
Sampling unit	Owners; company's representatives for corporate social responsibility and sustainability; other representatives willing to provide information
Extent (Location)	Germany; the Netherlands
Time (Year)	2020

Finding different companies have been done in three ways. First, it has been looked into online stores that specialise in sustainable products or online stores that specifically focus on bamboo products in order to gain knowledge on what brands there are. What online store have been used can be found in Table 3. This way, it has been investigated further whether these are German or Dutch

brands. The second way was using the search engines ecosia.org, google.de, and google.nl and try to find companies with a variety of German, Dutch, and English search terms that can fall into the different industries such as 'Bambus Möbel,' 'bamboe productie,' 'or 'bamboo packaging Netherlands.' The third way was through the researcher's personal network as well as by asking interviewees whether they could suggest other companies that might be interesting for this research. Whether a company is interesting for this research has been determined by the researcher on basis of the information and products visible on the company's website.

Table 3: Online Stores

Name	Country
avocadostore.de	Germany
laguna-onlinestore.de	Germany
cayboo.nl	Netherlands
misterbamboe.nl	Netherlands
koningbamboe.nl	Netherlands

Once a list of possible companies has been created, the companies were contacted via email stating the intentions of the research and formulating a research participation request. Occasionally, reminder emails have been sent out once no response has been received after two to four weeks. The email correspondence, as well as the interviews, were in German for the German companies and English for the Dutch companies. The sample size has been determined by the number of accepted responses. The low response rate for this research seemed to be influenced by the summertime as well as the COVID-19 pandemic outbreak. In order to increase the participation rate, it was decided to offer anonymity for the ones that wanted to keep their privacy but still were willing to help with their participation. Respecting the wish for anonymity is to be seen as no conflict for the aim of this research from the researcher's point of view. The designated industries to the participating companies are based on industry categories as they have been mentioned in chapter 2.1. It was tried to split the ratio of each participating industry based on the relevance in the international market as published by INBAR (2019). However, the acceptance of the research participation request determined this ratio strongly, due to the research circumstances.

Appendix 3 presents an overview of the interview partners for this research. In total, there were 11 manufacturers participating in this research, five from Germany and six from the Netherlands. To present the information in a unified way, each company is referred to a number. In the end, three companies each are presented in consumer items (Company 1, 2, 3), construction and finishing materials (Company 4, 5, 6), and furniture (Company 7, 8, 9), as well as two

companies in the textile industry (Company 10, 11). Company 1 distributes everyday products for the kitchen, bathroom, office, and other consumer items. For this study, it was mainly focused on their bamboo tableware. For Company 2, that has a similar product portfolio, the focus of the answers lay on the product range of table games. The Company 3, the last participant for the consumer items, distributes compostable packaging material and disposable tableware. Here, it was mainly focused on their compostable or disposable products made from bamboo. Their new line of 'Durables' like bamboo cutlery sets played a marginal role for this study. Company 4 offers decking boards, privacy fences and other similar products made from bamboo. However, for this study, it was tried to focus on the decking board products. Company 5 also offers floors, fences, and panels, but also products made from bamboo canes. Company 6 provides a wide range of products, from frames to stairs, but also other carpenter products for offices and restaurants like bar tops and restaurant tables, which the interviewee gave most of its examples for. Unlike Company 6, companies in the category of furniture do not provide construction and finishing materials. Company 7 offers wedding sheds and other furniture made from bamboo canes. Its products have been to a large extent being manufactured in a traditional way in the Philippines. Company 8 offers indoor lightning products and Company 9, a small manufacturer of furniture, offers a portfolio ranging from work tables to shelves and seating furniture. For the textile industry, Company 10 presented insights into primarily underwear garments made from Bamboo. In contrast, Company 11 focuses on the production of luxurious t-shirts and sweaters made from bamboo.

Between the 19th of June and 31st of August 2020, there were three email interviews taken, four video conference calls, three phone calls, and one face-to-face interview with an on-site visit. The total interview time for all interviews was 265 minutes (4 hours and 25 minutes), with an average of 33 minutes per interview. In total, three companies wished to remain anonymous as well as two respondents of companies that are were fine with presenting the company's name. Based on the participants with no anonymity, the female-male-ratio is 1:6. The position of the respondents were primarily the owners of the businesses, but also one sustainability consultant, one CSR advisors, and one key account managers/marketing & branding managers were participating, making it a highly credible data collection. For more details on each individual interview, please refer to Appendix 3.

3.3 Data Analysis

The final element of the research element proposed by Saunders et al. (2009a) is with the data analysis. After primary data collection through interviews, the audio-recordings were transcribed. In order to reduce the needed time for the transcription process, Saunders et al. (2009a) propose either hiring a touch typist, using a foot-operated start–play–stop play mechanism, using voice-recognition

software, or focusing on only transcribing passages that are considered relevant to the research, which is also referred to as data sampling. As this research is done with limited resources, the last proposed method of data sampling has been applied. To transcribe the interviews of this research, the software InqScribe was used.

Once the data collection is completed and the transcription is done, the data needs to be analysed. For this, Miles and Huberman (1994) have described an interactive model that shows the different components in data analysis. They propose that there is an interaction between the data collection, data reduction, data display, and conclusion drawing until the very end (see Figure 5).

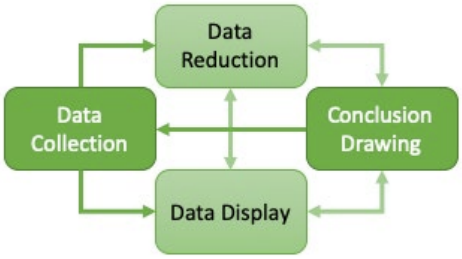

Figure 5: Components of Data Analysis: Interactive Model (Miles & Huberman, 1994)

According to the model of Miles and Huberman (1994), data reduction is aiming at finding ways to reduce the data through selecting, focusing, or simplifying it. This can be achieved by summarising, coding, teasing out themes, or making clusters (Miles & Huberman, 1994). However, Saunders et al. (2009a) argue that analysing qualitative data needs to be seen as a process without standardised forms, due to the many diverse features it encompasses. Nevertheless, they argue that there are three major types of analysis processes: summarising of meanings, categorising of meanings, and structuring of meanings using narrative. Structuring the meaning by using a narrative approach can be seen as a good process in circumstances, where a sequence of successive events is of importance to the outcome and are often collected through in-depth interviews (Saunders et al., 2009a). In contrast, summarising and categorising the meaning of data requires an approach of coding. Applying coding means that, for example, text excerpts are given a specific number or name to simplify the meaning and focus on the broader feature of this text excerpt to be able to identify overlaps with other text excerpts (Hair et al., 2016). However, the difference between the two processes lies in how the interview excerpts are handled. On the one hand, the idea of summarising of meanings lies in condensing information from the interviews and may rephrase them, making it also a more viable option for researches that require a second data collection round (Saunders et al., 2009a). On the other hand, the idea of categorising of meanings is used where it is possible to group the data, most commonly derived from the researcher's data set, terms used by research participants, or the literature and theoretical framework that has been identified and developed (Saunders et al., 2009a; Corbin & Strauss, 2008). Saunders et al.

(2009a) argue that his process is often used where inductive approaches are applied. In addition, they argue that it may be a suitable option for some researches to quantify certain occurrences within the collected data. Along with this data reduction, Miles and Huberman (1994) propose the data display process, where the data is put into a compact format that allows the reader to easily grasp the information on one glance. They describe that this can be done in different ways, such as matrices, graphs, charts, or networks. Furthermore, they argue that, with the help of data reduction and data display, it is possible to draw conclusions, meaning identifying relationships, patterns, or explanations. The authors also argue that, in some research cases, conclusions are resulting in a new round of data collection.

For this research, the data reduction has been done by categorising of meanings. As the C2C principle is addressing different elements, and the interview questions have already been structured in a particular way to address them separately, this process was able to be applied. Therefore, based on the conceptual framework and the interview structure, this research categorises the text excerpts from the interviews into different topics that are linked to a specific C2C category (see Figure 6). For example, this means that the category of Material Health is addressing all the interview findings that are linked to the topic of '100% biodegradable' and 'Cradle to Cradle.'

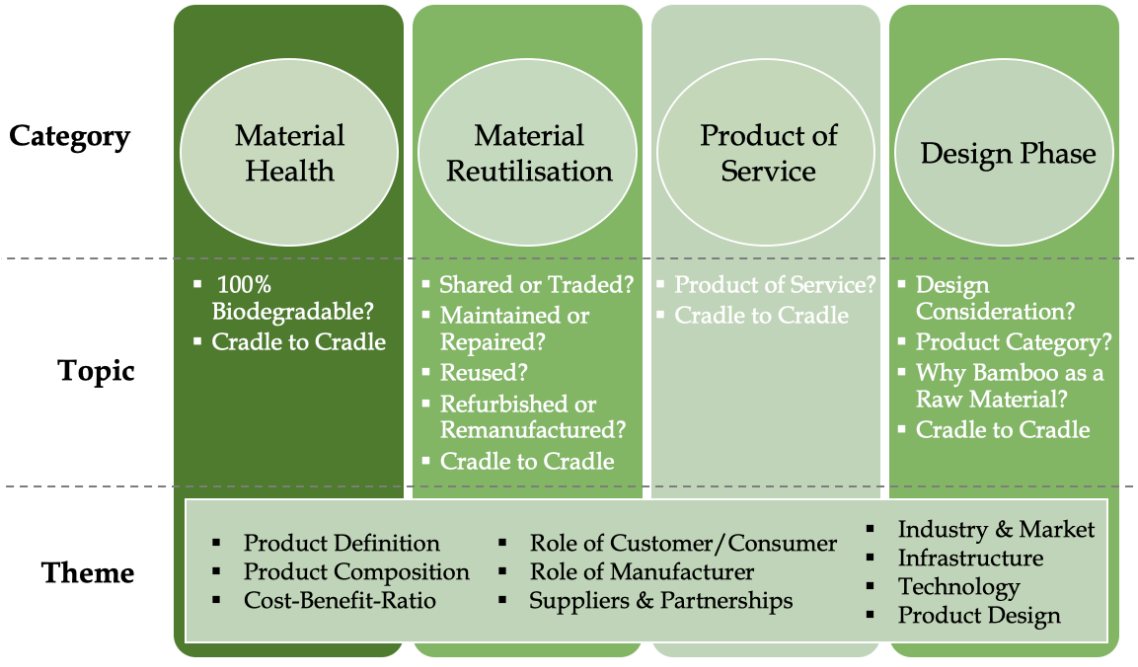

Figure 6: Relevant Linkages for Data Analysis

For better structuring the text excerpts, a spreadsheet has been created that lists the industry, company, topic, code 1, code 2, and the actual interview text excerpt. Then, certain key terms have been identified in the text excerpts. These terms were listed in column code 1, and, depending on the complexity of the

information, may require another term that has been stated in column code 2. During the analysing process, codes were reduced to only one code per text excerpt and/or they may have been renamed depending on similarities to other codes or for providing better understanding. In total, 218 text excerpts were present, which led to 126 unique codes and 92 codes with the same term as others. Based on these codes, 10 different themes have emerged those are grouping the different codes based on similarities. However, these themes are presents across all topics. Also, because the industry may be seen of importance to the viability of the principle, having a clear overview of all the different codes was needed. Therefore, for this research, it has been decided to display the data in a table format, which can be found in Appendix 4. This way, it is easier to identify what codes belong to what topic and industry. Moreover, with an applied colour scheme, it is able to present what codes belong to what themes. To keep a clear overview, it was decided to delete codes those were double in a topic/industry field, resulting into 186 coloured codes. Overall, it was decided against quantifying the dataset, for example based on reoccurring codes, as some of the codes occasionally reoccur for the same participant, but only with different text excerpts. It would not allow drawing any concrete conclusions from this quantification. With the help of the themes and related codes, conclusions have been drawn.

4 RESEARCH FINDINGS

In this section, the research findings are presented. As this research compares four different product categories/industries, each category is presented individually. For this, it will be looked at the different topics covered in the interviews and present the information accordingly. This means that each product category starts with how the manufacturers categorise their products and why they have decided to use bamboo as a raw material. Then, it is presented the opinions on whether or to what extent the products can be seen as 100% biodegradable, covering the Biosphere. Afterwards, the opinions on the different material flows of the Technosphere are presented in each paragraph individually in the following order: shared or traded, repaired or maintained, reused, refurbished or remanufactured, recycled or upcycled. Then, it is presented the manufacturer's opinions on the PoS concept of C2C, followed by what elements have been actively considered in the design phase. Finally, for the categories of consumer items and textiles, due to the respondents' experience with the concept itself, additional information and opinions on Cradle to Cradle are presented.

4.1 Consumer Items

Data for the consumer items has been collected from Company 1, 2, and 3. All three of them described their product as a consumption product. The reasoning why bamboo as a raw material has been chosen where manifold. It ranged from being able to reduce plastic as a material, to take advantage of the bamboo's morphology with the lack of needed pesticides and insecticides as well as the fast harvest abilities it offers. However, market developments and compliance with the company's mission and vision were addressed also.

Looking at whether the products can be seen as 100% biodegradable, depends strongly on the product, resulting in two company's answering no. While bamboo tableware needs to rely on the additive melamine resin, the table games have certain additional components that cannot be considered 100% biodegradable, but makes the game complete, such as a fleece textile or tokens made from stones. Despite the choice of using materials that are not 100% biodegradable, Company 2 tries to minimise the ecological footprint by carbon dioxide (CO_2) compensation measures for its transports. Also, as it recognises the challenge of the comprehension of the entire production process, independent testing, certifications, as well as on-site supplier audits are done and required. For that, communication with the supplier is essential.

"It is often a lengthy process to explain to the partners why it is so important for us not to use certain materials, unfortunately there

is often a lack of understanding here. Nevertheless, we have always been satisfied with the result so far and the many explanations have paid off."

- Company 2

While the other two product ranges need to rely on non-biodegradable additives and components, products of Company 3 are designed for single-use and are fully compostable and therefore filling a market niche in the industry. To ensure high sustainable standards, it uses a matrix that helps to address different criteria. Overall, the criteria are looking into transportation distances, EU/non-EU production location, the sourcing and scarcity of the materials, as well as the degree of compostability, biodegradability, and recyclability of its products. For the latter, it also considers whether it is a mono-material use or not, as a mono-material use allows better recycling rates. Furthermore, different standards and certifications are looked into. These standards and certifications address food safety-, quality-, environmental-, and energy management, as well as labour conditions and water use such as water efficiency management systems. However, it realised that for very natural products, as the ones it distributes, there is a lack of certification possibilities.

Whether a product is shared or traded between customers also depend on the product. Because tableware is considered a product that everyone is owning already, a sharing or trading them is seen as unlikely. For table games, it looks different. With the reduced interest of the games by children with time, mothers could pass on the games to other mothers and their children. For disposables and packaging of Company 3, on the other hand, it is seen as impossible to trade or share them between customers, as they are designed for single use. However, its durable lines it is seen as an option to do so.

Possibilities for repairing or maintaining the product is not seen amongst the companies for such consumer items. It is seen as an uncommon practice to repair tableware. It has also been stated that repair and maintaining options for table games bear no relation to the price of the products themselves, meaning the cost-benefit-ratio is seen as low. The single-use design of the disposables and packaging also does not allow any repair or maintaining option. The same goes for the durable line with bamboo cutlery. Here, the company decided to focus on the end of life options and encouraging the consumers to recycle the product.

Looking at the option of reusing the product, it is clear that the disposables and packaging are not intended to do that. However, the tableware with its long lifespan as well as the cutlery has the ability to do that. The table games can not only be reused for multiple game nights but also be used for different purposes. For example, building blocks can be used to even out rocking tables or used as dinner mats. In this sense, the consumer's creativity is addressed and is seen as endless.

Refurbishing or Remanufacturing the product is seen as not applicable for the consumer items. They are either not designed for them, due to the single-use or they are seen as unrepairable. For table games, in theory, it would be possible to repair them. However, this service is not offered, which requires consumer initiative to bring it to an external workshop, where they can get the service done.

Recycling and upcycling options and abilities are not available for the products in this specific research for different reasons. The tableware's synthetic additive of melanin resin makes it recyclable for its purposes. For the table games, it is up to the consumer to recycle or upcycle the components of the games or not. However, from a business perspective, the cost-benefit-ratio is too low in order to implement recycling or upcycling options for this kind of products. Disposables and packaging can be recycled, but unfortunately not for the same product. The issue lies here within the use of the disposables and packaging, as they get in contact with food. This creates food safety concerns, making it impossible to use recycled materials for its products, because of the unknown use of this material. However, it is tried to use waste stream materials, meaning materials that are seen as waste in other productions are utilised, such as sugar canes or palm leaves. Furthermore, the production location is seen as essential, as Company 3 decided to source the materials it produces locally, making it also difficult to use its own recycled material, considering its main distribution location in Europe and manufacturing location outside of Europe.

When considering a business model with the idea of PoS, it is clear that the participating companies see it as inadequate for its type of products. For both, the tableware as well as the table games, the cost-benefit-ratio is anticipated too low to make it a lucrative business model. For the single-use disposables and packaging, it is seen as too difficult to return them directly. With the focus of Company 3 on end-of-life options with recycling or composting their products, this business model is also seen as inadequate. However, it tries to connect different parties to make the composting reality.

> *"The client says 'I would like to have your products, but we also would like to have them in a composting machine.' So, then we work together with our partner and we bring that together. It is not a service we provide, but we make sure that we work together on that."*
>
> *- Company 3*

This external service works best for business customers those are able to use products of Company 3 in a closed environment. These could be festivals or any other gathering outside that allows an easy collection of the used products, while making sure all the majority collected waste is able to be composted. Although it is not applying the leasing concept per se, it goes a step further by offering a solution returning the nutrients back into the cycle.

Considering the elements stated above in the design phase, it is clear that the companies have to deal with a trade-off situation. Company 1 states that, although it is eager to use sustainable materials, it also needs to weigh the advantages and disadvantages of the materials used. Company 2 sees the design phase as important also, as the product not only should be sustainable, but also stylish at the same time. Company 3 is even in a position to aim for a 100% biodegradable product, as the market offers all needed materials with that quality. To ensure this quality for the end product, appropriate certificates are considered also when designing the product itself.

Next to getting an understanding of the feasibility of the different elements of the C2C concept, Company 3 has experience with the concept itself. It has been invited to and joined the so-called 'Circle of Friends,' which is a network- and lobby organisation of different companies whose vision and mission are aligned with the concept's principles. It helps the company to not only with feasibility related issues but also with creating awareness of sustainability as a whole.

> *"A knowledge partner as Cradle to Cradle, that works from the same philosophy, can help us in that, spreading the knowledge from a different point of view and not only on the technical aspects. They are creating this awareness and creating this kind of deeper understanding of what sustainability is. Because people seem to see this sustainability as something like a binary system, 'Yes' or 'No.' It is more fluent than that. It is a continuous process. It is not always perfect. No, it is never perfect. "*
>
> *- Company 3*

Therefore, Company 3 sees the advantages of being part of the organisation in getting feasibility support, sharing knowledge, but also creating awareness for the bigger cause, as the latter cannot be achieved alone. Furthermore, C2C is considered big in Western Europe, which matches with the operating market of Company 3, making it ideal to be part of this organisation. In regards to the C2C certifications that one can obtain, Company 3 might consider them in the upcoming year. However, as they are rather expensive, and it sees other certifications higher on its priority list, it postponed making a final decision on it.

4.2 Construction and Finishing Materials

Data for construction and finishing materials has been collected from Company 4, 5, and 6. They described their products as raw material, construction material, or B2B product. The reasoning why bamboo has been chosen as a material is

based on its versatility, but also the educational background and general experience with the grass, as well as identifying a market niche for it that shows potential were decisive factors.

Looking at the degree of biodegradability of their products, it is strongly dependent on necessary additives and additional components. While the bamboo canes as such can be seen as 100% biodegradable, its use, for example as a fence, may require weather resistant wires for mounting purposes, as well as a lacquer for surface sealing making it also more weather-resistant. Products of Company 4 and Company 6 rely on a manufacturing process based on compressing and moulding the bamboo fibres. For that, they require between 5-10% resin, like phenol resin.

> *"This resin is not 100% biodegradable. This is something we wish, and we can pursue, but for now, no glue has shown to be durable enough to have a long-lasting life."*
>
> *- Company 6*

Company 4 undertakes similar actions by constantly looking for biodegradable alternatives, with currently little success. However, it is optimistic that there will be such an alternative emerging the market in the future. Another element is the heat treatment process that kills the cells within the bamboo, which are required for the fungus to biodegrade the bamboo. From a durability point of view, Company 6 sees this as essential to make long-lasting and sustainable outdoor products. In addition to the heat treatment, certain products rely on additional components. Company 4 uses aluminium for the substructure of the decking boards. Aluminium offers higher construction flexibility while offering the needed stiffness for the terrace in comparison substructure made from bamboo. Furthermore, the dead weight of bamboo is five times higher than aluminium, resulting in lower CO_2 emission for transporting aluminium. Nevertheless, aluminium is not biodegradable and requires high amounts of energy. Therefore, Company 4 has a cooperation with a supplier that only uses renewable energy for its production and works with only recycled aluminium.

When it comes to sharing or trading the products amongst customers, the opinions are mixed. It ranges from that it is not aware of any practices, to that it could not imagine that these practices are done. Only Company 6, with its carpenter materials for restaurant furniture, believes there are practices when it comes to second-hand furniture. They can be refurbished by the customer with sanding and lacquer, those can be put on the Dutch selling platform Marktplaats.

Whether a product is repaired or maintained, strongly depends on the company and its business model. The business model of Company 6 enables direct end customer contact in, for example, the restaurant industry. It offers services for sanding table- and bar tops and putting a new layer of lacquer. Com-

pany 4 and Company 5, on the other hand, sell its construction material to retailers and other industrial partners, leading to not having direct contact with the end customer. Company 5 sees its B2B customers as the one who needs to initiate this service. Despite the lack of direct end-customer contact, care products are either offered or directly applied to the product. For example, Company 4 provides water-based and solvent-free care products such as oils that can be applied to decking boards. Although decking boards are considered outdoor products, its oils are certified for indoor use also. Company 5 also addresses repairing and maintaining from a different angle.

> *"We always recommend constructive weather protection, so that you install it in such a way that it lasts as long as possible, but that you should rather accept the natural weathering than to make this questionable effort so that it remains visually beautiful. Bamboo naturally has a very dense, hard lacquer-like surface, which also offers a certain degree of weather protection. And even if surfaces no longer look so beautiful, they last a relatively long time."*
>
> *- Company 5*

Constructive weather protection measures are, for example, the avoidance of direct ground contact of the bamboo or considering a roof construction above the bamboo. This would prolong the durability and requires consumer education by the company before the purchase. Despite that, Company 5 states that it also depends on the type of product. If a product has a high value and is considered complex, like a bamboo bicycle, measures with lacquers increase the lifespan should be taken.

In general, construction products seem to have limited possibilities when it comes to reusing the product for example for different purposes. In theory, Company 4 sees possibilities to use the decking boards for fences. Also, Company 5 stated that its product can be reused as long as they are not weather-beaten too much. An example it provided was an exhibition stand made from bamboo canes that can be assembled, dismantled, and modified as often as the customer likes thanks to specially designed connecting pieces it also offers.

Similar to why maintaining and repairing is offered or not, refurbishing and remanufacturing products is influenced by whether the product is sold directly to the end consumer or not. Company 6 is able to take back old table- or bar tops, re-sand the surface and seal it with another layer of lacquer. It is also possible to simply repaint the old product, or return it that then can be put into a moulding machine and create a new, smaller product. Company 4 and Company 5 do not have end-user contact, leading to a need for consumer initiative.

Upcycling such products is to be seen as limited. Theoretically, decking boards can be upcycled to sidings or fences. However, this is not something Com-

pany 4 actively pursues. Company 6, on the other hand, is able to reuse any returned Bamboo material that is bigger than 20 mm by repurposing it, for example, as wall decoration. Nonetheless, it also argues that there are no set prices for an amount X of returned products, as there is no real market for it yet. Only sawdust, shavings or off cuts have a specific value, as they can be further processed to compressed wood. However, getting the returned bamboo products into such small dimensions that they can be processed for this kind of recycling purposes, is not seen as easy. Company 6 does not know a process that manages this task. Company 5 has tried to shred pieces with a conventional wood shredder, which resulted in machine failures as the long bamboo fibres blocked essential machine parts. Therefore, a new process is required that currently is unknown if it already exists or not. Whether recycled bamboo material is used for its products itself, Company 4 refers to the availability of bamboo in general.

> *"This is, for a plant that grows very quickly, not such an issue. We have no supply problems. In China alone there are now four million hectares. We now have the problem how to use it completely."*
>
> *- Company 4*

This element of the great availability should be considered when having a debate about how much dedication we should give the topic on finding solutions for utilising recycled bamboo material for other bamboo products. There might be other areas that seem to have higher priorities.

Looking at the PoS concept, the experience and level of interest are mixed. While Company 5 has no real interest in this business model due to the focus on selling items rather than renting, Company 4 is fond about the concept and may see it as a viable option for leasing complete decking boards to restaurants for a fixed period of time. Offering a service of annual painting for maintaining the surface coming with the leasing could also be an interesting option in this case. Company 6 has already attempted to build this kind of business model for restaurant tables. However, due to a lack of time, the business idea has not been fully established. There is still an interest in it, but it also recognises the unknown factor of the market potential.

Looking at the design consideration of all the C2C elements, Company 5 states that there is no direct consideration. However, for some products, the assembling played a vital role. For example, the exhibition stand that it offers is constructed with a fitting system that enables doing without cutting and screwing the bamboo canes, leading to greater material-friendliness with quick and simple assembly and disassembly options. The assembling has also been in the focus for Company 4. Its decking boards and the substructure are designed in such a way that no cutting, milling or drilling is needed. Furthermore, each bamboo board has two A-sides, meaning the boards can be used from both sites. Therefore, in theory, the decking board could be used twenty years from one site,

and twenty years from the other site. Design considerations for Company 6 have been more focused on refurbishment. Its restaurant tables have been designed in such a way that it is possible to refurbish the table by sanding it by one mm each time. This results in a total number of five refurbishment cycles. Being able to consider this design element was only possible because of the strategic choice of also processing the products by having the knowledge and machinery also. Hence, it not only acts as an importer for half products used by other manufacturers or retailers, but it also sells directly to the end customer, such as restaurants, leading to an advantage over competitors.

4.3 Furniture

Data for furniture has been collected from Company 7, 8, and 9. While Company 8 and Company 9 describe their products as a consumption product, Company 7 describes theirs as durable products but also argues it should be up to the customer how to define the product. The reasoning for choosing bamboo as a raw material has been its traceability, the enjoyment of the work process, as well as the ecological aspect of bamboo for Company 7. Company 8 more looked for a wood alternative and was convinced about bamboos great versatility and availability. The founder of Company 9, on the other hand, experienced bad practices with even certified wood, resulting in looking for a better alternative.

Whether it is possible to produce the product in such a way that it is 100% biodegradable, depends on various factors. Company 9 states that there is no glue on the market that is sustainable and strong enough for its purposes at the same time. Looking at lightning products of Company 8, in some designs weaving the bamboo together is enough. However, occasionally, the design requires gluing the bamboo together. It managed to find a glue that is biodegradable and works for its purposes at the same time.

> *"I know we have even someone, like a supplier, who took it even further. He has a patented glue. It is not chemical, non-coloured, non-toxic. It is really perfect. And then we make this beautiful mould, where we can make anything out of it, from bio forest waste. So, you grind up any kinds of branches. And then they can make it in any kind of mould-shape."*
>
> *- Company 8*

Despite the advantage of the biodegradable additives, lightning systems rely on electrical parts those are not biodegradable. Nevertheless, an easy separation between the different components has been considered. Company 7, on the other hand, needs to deal with an outdoor environment for its wedding sheds.

As the roof is made the traditional way with leaves, this causes some problems. The windy climate as well as wild animals like birds that like picking in the roof, perhaps for nest-building, are causing damage to it, resulting in the use of a synthetic net over the entire roof surface. Although there could be other methods with dealing with the wind, they do not solve the bird problem. Other additional components are metal bolts to ensure stability between each module. Additionally, depending on customer demand, a water-based, children-friendly stain or a biodegradable oil is applied to the bamboo canes.

Whether a product is shared or traded between customers, also depends on the product itself. Company 8 is not aware of any such practices. Company 7 argues for its wedding sheds that this is unlikely to do, as they are too big to do easily. Company 9, on the other hand, is aware that this is sometimes done, as customers ask it whether it knows any other potential customers, who are interested in their products. There seems a market for it, but participating in it, would require a different business model as it currently has.

Whether maintaining and repair options are offered and in what form, depends on the product itself. Company 7 faces certain challenges that are still ongoing.

> *"The roof is a natural material and has a limited lifespan, of which we cannot yet say exactly how long it will be. The experience is only available in the Philippines."*
>
> *- Company 7*

Because of the relatively recent establishment of Company 7, it has not made the experience how such a product is coping with a different climate other than the one in the Philippines on a long-term basis. That is one of the reasons why it has decided to offer also maintenance and repair services for its wedding sheds. This can only be done on-site, due to the product size and its embedment. Company 9 also offers maintaining and repair options mostly for its office furniture as they are occasionally treated with aggressive cleaning agents, damaging the surface. Then, it offers re-sanded them again. Also, in some cases, it replaces bamboo slats for other products. Looking at the lightning products of Company 8, no such options were provided. The reason behind it was down to the lack of infrastructure for returning the products, as well as the general cost-benefit of performing these services. Furthermore, it wants to challenge the status quo of the customers' perception that products are flawless. A small scratch or a small hole in a natural product as theirs should not be seen as a defect in the product itself. Therefore, this consumer education plays a role here.

Furniture in itself can be reused many times Furniture of Company 7 can be used for indoors as well as outdoors, its fences can be used as wall decoration, and its mats can be used from filling material to screen walls. The product range 'Arc Tables' of Company 9 is also designed for office and home use in mind.

Company 8 describes that part of its products can also be used as baskets or holders, depending on the shape of the lamp itself. However, this option in itself is not communicated to its consumers.

Refurbishments and Remanufacturing is another option that offers a circular approach. Company 7 can only do that on-site, where the wedding sheds are located, due to the product size. Company 9 addresses the material choice of it. Avoiding veneer as a material and choosing bamboo, which is harder and smoother than oak, makes good material to reuse it. It believes it is the manufacturers' responsibility to get involved in it. Company 8, with its lightning products, has doubts on the feasibility for its products, as bamboo is seen as quite fragile, making it hard to refurbish it. Also, it has concerns about the feasibility of it.

> *"We put out a new collection and it lasts for four years. So, if it is not sent back ten years later, and we don't have this product anymore, we cannot refurbish it."*
>
> *- Company 8*

It argues that currently there is a lack of proof of concept in it. It believes there might be a potential to implement it, but can be seen as costly. Currently, it does not have the internal structure to implement such a service. Furthermore, it argues that, in contrast to the electronic industry, there is a lack of resellers for refurbished goods in the interior industry.

The recyclability and upcyclability of furniture depend on different factors. While for Company 7 with its products mainly from bamboo canes, in theory, it is possible to recycle or upcycle old products by 100%. It can take a lateral section and can make cups or vases out of it. However, this is very price-sensitive, so it depends on whether the customer is willing to pay for this. Company 8 sees upcycability options from other industries related to its products. Baskets can, with a simple whole, be turned into a lampshade. Although bamboo is recyclable, and it is able to use recycled materials for its products already, it does not recycle bamboo itself. From its perspective, an integrated system is needed, which is not in place yet. Additionally, Company 9 states that it is on the highest standards the market can offer and that there is currently no technology out there that can offer this.

When looking at the PoS concept for the three companies, it seems clear that they see some challenges with it. Company 9 sees an increase in prices with this concept, as it needs to start being represented on specialist trade shows in order to make one visible. Furthermore, with such a business model, fast delivery is key, which requires high stocks. Overall, it is unsure of the demand on the market related to that. Company 7, being run only by the two owners, sees this concept also as a very resource-intensive when it comes to assembly and dismantling the wedding shed, which is not feasible with only two men. In addition, due

to the product size, transportation can cause high expenses. Therefore, it believes the overall cost-benefit would not add up.

> *"I don't think that it would have so much added value that it's worth running for it. You could better say: 'You buy it, and we get around for any repairs. But it is your responsibility and I am not under any warranty obligation.' (...) Also, it is a natural material. Natural material always has to be treated and cared for a little differently."*
>
> *- Company 7*

Concerns about the warranty obligations are rooted in people's behaviour. It is perceived that people do not take good care of products they personally do not own, which could question the ability to refurbish the returned products for another rent out. This aspect is important when renting out such a natural product as theirs, which requires more care in handling and using it. Company 8, on the other hand, sees great potential overall with the concept. It is believed that, although it is still a niche in the market, people's mindset will change with time not wanting to own products anymore. However, such a business model requires an integrated system, which it does not have at the moment.

Question remains how far the companies have considered the different C2C elements in their design phase. The speciality of Company 9 lies within building furniture as sustainable as the market can provide currently. Fusing sustainability with design is its intrinsic motivation. Company 7 has a similar intrinsic motivation. It focuses on making the product the traditional-Filipino way with mainly bamboo canes. However, it realised that the traditional way uses also tropical hardwood for the substructure which it considers critical. That led to the decision of not only using bamboo for the house itself, but also for its substructure. Additionally, as the product is manufactured in the Philippines, transportation had a big influence on the design phase. While other companies manage to transport only five to six wedding sheds in one container, its modular building concept and design allows it to transport twenty sheds in one container with no packaging material needed. Company 8 has thought of the end of life phase of its products. Similar to Company 7, it has adapted a modular building concept, where the product can easily be disassembled again. That makes it easier to recycle the electric parts and the biological parts separately. However, it is admitted that considering all the C2C elements in the design phase requires an integrated system, that is not present yet.

4.4 Textiles

Data for textile products has been collected from Company 10 and 11. While Company 10 clearly sees its product as a consumption product, Company 11 describes its products as a treat for oneself, as well as a product that its users identify with, including joining a community. The reasons for using bamboo in the textile were identical for both companies. The wearing properties, being very soft on the skin, is an important factor for using bamboo textiles. Also, the product story with the sustainability aspects that can be communicated to the customer has been mentioned as reasoning. Nevertheless, Company 10 also addresses that there are false claims when it comes to bamboo textiles. Often bamboo textile is described as antibacterial. Although this claim is true when talking about bamboo as raw material, when being chemically processed, it loses these properties.

When looking at the 100% biodegradability of their products, both have to rely on the current status quo of technology. In order to make the garments soft, bamboo fibres need to be broken down with acid. Because the bamboo fibres are relatively tough, it requires more acid than for other raw materials for textiles. Producing yarn, the natural way from bamboo, as opposed to the mechanical way, it will not be as soft on the skin. This was not seen as an option for Company 10, as it produces undergarments. Company 11 also addresses the composition of the yarn itself. Its intention has been to create a t-shirt that has no synthetic material in it. To achieve that, it has two different kinds of shirts in its portfolio. The first one is made of 100% bamboo viscose. The second option is a composition of 60% bamboo viscose and 40% organic cotton. The reason for offering the second option results from challenges during the dyeing process.

> *"If you have a stronger fabric, like normal cotton, it is easier to dye it without having damage. With Bamboo, it is very thin and fragile. You also have to be very careful with the dyeing process. This makes it costlier and more time consuming. Everything's hand made."*
>
> *- Company 11*

Because of these challenges, the 100% viscose bamboo shirts are dyed the natural way with only plant-based materials such as mango fruits or indigo leaves. Although finding an alternative to the chemical-based dyeing process, it is 12 times more expensive than the chemical-based one. This is reflected in the selling price. Because not every customer is willing or simply not able to pay such a premium price for t-shirt, it introduced the cheaper mixed composition option with still carefully chosen materials. Often, it is also seen as an introduction option for inexperienced people wanting to see whether they like bamboo viscose

in general. Despite the challenges, both companies are having suppliers, who offer closed-loop solutions for processes involving chemicals. Additionally, Company 11 is PETA-certified and does CO_2 compensation measures to underline its sustainable intentions.

When looking at whether their products are shared or traded between the customers, there are different options. Company 11 can imagine that this could be done in second-hand stores or on online platforms, but it is not actively facilitating it as it would not fit its brand image of luxuriousness. Company 10, on the other hand, argues that it is unlikely that there is a market for second-hand undergarments.

Repair and maintaining options for the two companies are seen as not feasible. Company 11 argues that, in general it is a great idea, it also argues that it is resource intensive. The current set up with the warehouse would not be able to cope with returned items for repairing. Furthermore, having these services would conflict with the brand image as it would push it more towards second-hand clothing. Company 10 also argues that repairing clothing is very price sensitive to the product itself. It might be the case that people repair an expensive leather jacket, but for undergarments, it is unlikely that they will take the energy to repair it or get it repaired. The overall low prices within the industry caused by fast fashion are fostering this behaviour.

> *"I think first the consumer needs to be educated and really get a grip that we can't just start chucking everything. (…) We need education. You can see it now in all the repair shops. It all is coming with the generation Y or Z that they are now beginning to start thinking about it and start doing it."*
>
> *- Company 10*

Consumer education is seen as essential to solve the dilemma with garments and awareness is getting stronger. However, it argues that the majority of the textile industry, including its own, still has business models that rely on the number of items sold. Repairing services would have a counterproductive effect on it.

While clothes are certainly are reusable for the same purpose, using them for different purposes is seen as difficult. The only option seen is using it as a cloth. However, as cloths generally are ending up on the landfill, it is seen better to simply recycle it rather than reusing it for different purposes.

Similar to repairing the garments, refurbishing or remanufacturing is seen as difficult for their product range. The previous mentioned consumer's mindset, as well as the overall industry willingness, is not there yet to be able to properly implement such ideas on a larger scale.

Looking at the recyclability or upcyclability, Company 11 believes it is doable. Having a machine that allows making micro-fibres out of the old garments,

would enable to make anything you want out of it in the end. However, for its own products, it relies on virgin material again to keep the branding of luxuriousness up. Company 10 pointed out challenges that come with recycling and using recycled material for its own product range. In order to operate on such concepts, the companies have to rely on high and constant enough influx of old garments to be recycled. This cannot be guaranteed for such a small company as their own. Furthermore, not only is it expensive to manage, but the returning options are seen as impractical and unattractive to the consumer. Return boxes, similar to the ones the company H&M offers, is seen too much of a burden for most consumers and self-addressed return envelopes are seen as impractical, considering keeping the envelope is needed after the use of the garment, perhaps after a year or so. However, companies need to rely on the consumer to return the garments in some way with these concepts. In addition, concerns about material quality arise.

> *"Inherently, that is the whole problem about circular, or even recycling bamboo. It will lose its inherited strength. After recycling it a couple of times, you cannot have bamboo on its own. We have to start adding polyester yarn or whatever to maintain the strength properties."*
>
> *- Company 10*

Keeping the material in a closed-loop, as proposed in CE, does not prevent a reduction of material quality, that in some sort of way need to be compensated for. When looking at upcycling options, Company 10 has seen great ideas with it. However, with undergarments, and the former use, it is seen as more difficult to do it.

The PoS concept, in general, has great reception with the two interviewed participants. However, Company 11 sees this concept only working with certain products of a certain value, like bicycles. Also, this concept needs to be part of the entire brand. For its own products and brand, it is perceived as too complicated. Furthermore, there is an uncertainty of whether this kind of business model is working for t-shirts. Company 10 also argues that there is a lack of infrastructure to begin with to implement it for its company. Part of the general issue here also is the manufacturing location. This concept would require a shift of this location closer to the company and its customers. Additionally, the CSR advisor's personal opinion, which is not necessarily shared by the company itself, is that this ownership concept as a whole is seen as the only way to create a more sustainable garment industry.

> *"At the end of the day, it comes back to us, and that is the only way that manufacturers make sure where it goes. Everything will be*

more sustainable, more durable. That inherently makes products cleaner and far more durable, the lifespan would increase, and the whole recycling becomes far more doable."

- Company 10

When looking at the design phase, both participants have not actively considered a circular approach in terms of recyclability. Company 10 argues that the main focus of the general textile industry lies not necessarily in improving recycling options, although there are also slowly businesses models emerging in this field, but rather in improving the status quo in the areas of water, chemicals, and energy use. Nevertheless, both companies have had a strong emphasis on choosing raw material that is considered sustainable. Intrinsic motivation for sustainability of Company 11, and its conviction of the great wearing properties of bamboo, led to the decision to design the garment as natural as possible. Despite the great interest in many of the C2C elements, Company 11 sees a lack of important forerunners that have the resources and the expertise to make an impact in the industry, for example by finding a better way to make bamboo fibres stronger. This way, more companies would also be deciding to choose bamboo viscose.

Company 10 has commented specifically to the applicability of practices in regards to C2C, due to the interviewee's knowledge as a CSR advisor. It has been argued that the chemical collection process, similar to the Lyocell method enabling fewer residues, is essential if one wants to apply the C2C approach. It helps to make it more sustainable and keep hazardous substances in a closed-loop. Despite the efforts, a chemical process will leave traces on the final garment no matter what. Therefore, it cannot totally comply with the C2C concept. Furthermore, the interviewee challenges the C2C recycling concept. As mentioned earlier, textiles lose their strength when recycled multiple times. To compensate for the strength, different material, such as polyester yarn, needs to be added. This is something that requires careful consideration.

5 ANALYSIS AND DISCUSSION

The analysis and discussion section presents the information based on the conceptual framework, meaning each category is looked at individually. As stated in section 3.3, each category discusses different topics that then has different themes identified. With that, is able to answer the sub-research questions those are linked to the respective category.

5.1 Material Health

As the Biosphere of C2C is implying that the final product's nutrients can be fully recovered by biological processes, identifying its applicability is done through the lens of the C2C category of Material Health. Information on this has been covered in the topic of '100% biodegradable' during the interviews. With that information it is possible to answer the first sub-research question formulated as the following:

1. How applicable is the Biosphere to the manufacturers' products?

Looking strictly at the criteria of 100% biodegradability of the final product, only Company 3 is able to comply with it. Its compostable packaging material and disposable tableware have the properties to fully biodegrade without any harm to the environment. The uniqueness of the company's products, in comparison to the other participating companies, is that it is the only product that is designed for single-use, resulting in the shortest lifespan of all products. Therefore, it can be said that the use phase determines the degree of durability needed. Although durability may play a role for disposable and compostable packaging also, for example, to keep its content fresh, the need for durability of the other investigated products can be seen as higher. The intended use of the final product is essential. It is a difference if the purpose of the product is only to bring your food from point A to point B once, or if its purpose is to provide seating multiple times. For example, a chair is not considered waste and is disposed if it has been sat on only once. Its requirement for durability is therefore placed differently. To ensure durability with bamboo products, companies need to rely on additives that are often not biodegradable.

Furthermore, the function of the final product can also be seen as a factor that determines whether the entire product is fully biodegradable or not. For example, if the product's function is to be worn on your skin, like a t-shirt, the bamboo needs to be transformed into an appropriate shape that it serves its intended function. However, this may require processes that rely on non-biodegradable additives for the production process itself, like an acid. Another example is a

lamp's function to provide light, which requires the flow of electricity. As bamboo itself is not conductive, the final product needs additional components, such as cables, in order to serve its intended use. These additional components are often not biodegradable. Therefore, it can be said that the applicability of the Biosphere to the manufacturers' products is strongly determined by the use phase.

Overall, it can be said that, if the use phase requires a certain degree of durability, shape, or function, it may be the case that the product requires additives or additional components to serve its intended purpose during this use phase. Currently, the requirement for non-biodegradable additives and additional components can be considered high for bamboo products of the participating manufacturers, making the ability to apply the concept presented in the Biosphere very limited.

As the majority of the participating companies are not able to comply with this part of the principle, getting an understanding of their challenges and needs would be the first step to solve the issue of non-biodegradability. As the companies operate in different industries but use the same main raw material, identifying similarities and differences with the help of the identified themes could enable focusing in a specific direction of the solution-finding. For this, the third subresearch question will be answered:

> *3. What similarities and differences can be identified for the manufacturers' challenges and needs with the principle?*

Despite the grouping of the companies into industries based on their products, the vast variety of the products within each industry even results into differences. However, the main challenge that all industries face is caused by the product composition. The need for non-biodegradable additives, like resin, glue, or acids is prominent across all industries and correlates with the findings of van der Lugt and King (2019). The textile industry, in particular, is facing the challenge of finding alternatives to the current acid-based process to break down bamboo fibres to get the desired material features. In contrast, the furniture industry is able to use biodegradable glue for its lampshades. However, other industries and furniture manufacturers need to rely on synthetic resins and glues as the current market cannot offer biodegradable alternatives those are strong enough for the products' purposes. This is also reflected in statements published by INBAR (2019).

Overall, the only choice companies have when relying on non-biodegradable materials or even toxic materials is to minimise emissions by selecting suppliers carefully. This includes suppliers offering a chemical collection process as a closed-loop system, sourcing their energy from renewables, or using recycled materials. In particular the chemical collection process, which is seen as the only solution for the textile industry currently, can be seen as an applicable approach for McDonough and Braungart's (2002) requirement for special care of hazardous substances.

Additionally, to ensure the needed quality general from the suppliers, purchase conditions, independent testing, supplier audits, and certifications are applied and proposed methods of the manufacturers. However, these are not without challenges. For example, single-use packaging and tableware products face the problem of available certificates in general for entirely natural products. Furthermore, the table games manufacturer stated that sometimes there is a lack of comprehension of its Chinese suppliers on why the product should not contain certain materials.

Furthermore, there are two other challenges companies face that influence the product composition. The first challenge is derived from the product design with a specific intended application environment in mind. Often, it requires non-biodegradable components, such as bolts, aluminium compounds, or synthetic nets, in order to guarantee the product's functionality and stability. While partially also applicable to consumer items, products designed for outdoor purposes have to withstand more environmental influences such as sun, rain, snow, and wind. Although a heat treatment process can help with withstanding some of the influences without using additional chemical use, it comes at the cost of the biodegradability of bamboo, as the process kills the respective cells within the bamboo.

What manufacturers can influence when dealing with the challenge of using additional components to ensure the functionality for the intended application environment is designing the product in such a way that it is easy to dismantle and separate biodegradable materials from non-biodegradable ones. While the literature has also recognised this as an important element of CE (van der Lugt & King, 2019), it can be said that it has been considered to a wide range in the different represented industries. Although, the argument of Cruz Rios et al. (2019) that disassembly is not in the primary focus of the construction industry is not confirmed for the participating manufacturers. However, it needs to be stated that the intentions of disassembly are different. While the Cruz Rios et al. (2019) propose disassembly from an intention of circularity, apart from one manufacturer, assembly and disassembly were mainly driven by flexibility and convenience for the participating manufacturers.

The second challenge companies face that influence the product composition is derived from the role of the consumer/customer. This is in particular true for the products within the construction and finishing materials as well as furniture industries, where a higher degree of customisability is given. If a customer wants the product to be treated with oils or lacquers, for example to change colour or reducing weathering and wearing out processes, companies naturally fulfil this demand. Although companies are able to determine whether their options are water-based and biodegradable, which they do, treating the bamboo would decrease how fast the product will be able to degrade nonetheless, as presented by van der Lugt and King (2019). One manufacturer has been stated that it would be better, for example for the bamboo canes, to accept the weathering process as bamboo canes offer natural protection on its own already.

The challenge of the role of the customers for construction and finishing materials as well as furniture is derived from the present mindset and education of the customers. Oils and lacquers on natural products like these will remain an offer as long as there is a demand for it from customers. To change this, two things need to happen. First, the customer needs to understand the benefits of bamboo's natural protection as well as the negative impacts of additional treatment processes for later use of the material. Second, the mindset needs to shift that natural products have to remain as visually beautiful as on the purchase date.

The textile industry faces a different challenge in regards to its customers. While the customer expects a certain degree of softness of the garment, that currently can only be achieved by using chemicals, manufacturers are only able to apply a natural alternative for the chemical-based dyeing process. However, as this process is costly, and the customers either are not able or willing to pay the extra price for it, demand is low in comparison to regular, chemical-based dyed garments. Therefore, it can be said that there are two options for change. Either the mindset of customers' needs to shift from an unconscious purchase behaviour, to a more conscious purchase behaviour that may result in lower purchases but of higher quality in terms of sustainability, or big industries need to find invest into finding more environmental-friendly production alternatives and scale these up. However, preferably, both options are tackled at the same time, so both benefits can be enjoyed.

5.2 Material Reutilisation

As the Technosphere of C2C is intended for products those cannot fully degrade biologically, and the vast majority of the products in this research cannot fulfil the 100% biodegradability, identifying the applicability of this metabolic cycle of C2C is seen relevant. In order to do so, it has been looked at the C2C category Material Reutilisation, which encompasses the topics (or cycles) of 'sharing or trading,' 'maintaining or repairing,' 'reusing,' 'refurbishing or remanufacturing,' and 'upcycling or recycling.' The concept of Product of Service can be seen as part of material reutilisation, but is addressed separately in section 5.3. With the collected information, the second sub-research question is addressed:

2. How applicable is the Technosphere to the manufacturers' products?

As the Technosphere proposes many different cycles to keep nutrients in the loop, it can be said that the general applicability is determined by many different factors and needs to be looked at on an individual basis. While it is possible to use maintaining products or sanding some bamboo products, it is also possible for some to use certain strategies like an end of life cycle, waste stream material, or constructive weather protection approach. All these aspects are driven by the type of product and customer preferences.

However, whether a cycle can be applied to the product also depends strongly on the company's perception on who is responsible in keeping the product in the cycle and whether the product itself is able to circulate in the proposed ways. Often times companies see challenges with a respective cycle, leading to the belief it cannot be applied to their product, or it is up to the consumer to contribute to this kind of circularity.

In some cases, it will also be questioned whether the degree of focus on keeping the material in a specific cycle is appropriate when looking at the broader picture. For example, despite the great prospects for bamboo to be recycled (INBAR, 2019), one manufacturer argues that finding recycling options for bamboo products should not be the first priority as there is no shortage of bamboo raw material. Furthermore, the degree of biodegradability and its intended lifespan play a role in the perception of whether the different cycles are needed or not. A fully compostable product as the single-use packaging and tableware does not require any kind of attempts to being, for example, repaired or maintained.

Overall, it can be said that some of the elements proposed in the Technosphere can be applied to the manufacturers' products. However, it requires careful examination on which products go with what cycles and how they suit the current manufacturer's operations.

In order to understand how to facilitate the idea of the Technosphere, and because the degree of applicability is strongly depending on what challenges the manufacturers face, identifying its challenges is seen vital. It may also help to get a broader understanding of what focus point could be set to help multiple industries at the same time. This will be examined by looking at the third sub-research question that is stated the following:

> *3. What similarities and differences can be identified for the manufacturers' challenges and needs with the principle?*

Looking at challenges with sharing or trading the products between customers, it is evident that the consumer preferences and their purchase behaviour play a role. For example, products such as undergarments are seen as not desired second-hand items and the widespread ownership of tableware is also perceived as a factor reducing the likelihood of using this specific cycle. Furthermore, for the wedding sheds, the product size on its own is to be seen as a reducing factor for sharing or trading it. Within the construction and finishing materials industry, it is often the case that there is no awareness of any of these practices in the industry. However, one furniture manufacturer is aware that there is a market for its products as the customers approach them to advertise these. Nevertheless, the manufacturer admits that, if they start contributing to this cycle as a manufacturer, a different business model would be needed.

Challenges also arise with maintaining and repairing options for bamboo products. When looking at consumer items, it is seen as an uncommon practice to offer such services by the manufacturer, as the cost-benefit of maintaining or repairing the products is too low in comparison to purchasing a new product.

The cost-benefit argument is also prominent in the furniture and textile industry. For lamps, the repairing price of the product is out of proportion to the selling price. The same argument goes for garments, although it has been stated that the initial value of the garments plays a vital role here. The consumer is more likely to get an expensive leather jacket repaired than undergarments, that, thanks to the low prices caused by fast fashion, is easily replaced.

The emphasis on the cost-benefit argument in for maintaining or repairing the product is also caused by the lack of customer education and customer motivation to contribute to the cycle. Therefore, the textile industry in particular struggles with that, fostering a lack of motivation within the industry to offer these services, as it would decrease the sale volumes. Consumer education on this matter is seen as a challenge in this area. Customer education is also prominent in the construction and finishing materials industry. An understanding of the importance of constructive weather protection to maintain the product is missing. One furniture manufacturer has also addressed the importance of the consumer understanding that natural products are not flawless, meaning repairing a product due to a small stain caused by the bamboo structure, does not make the product in itself broken.

Moreover, the infrastructure challenge is also addressed in the context of repairing and maintaining the product. Challenges with the given infrastructure are especially addressed by the textile industry as well as the construction and finishing materials industry. Offering these services are resource-intensive, need the logistical feasibility, and require direct customer contact. In particular the latter is seen to be challenging for the construction and finishing materials, as they often times use third parties, such as retailers or craftsmen, to sell their products.

However, even if there are no challenges with maintaining and repairing the product, the role of decision making still lies for the manufacturer. If the manufacturer brands its products as luxurious and repairing and maintaining products is not seen as luxurious, offering these services may conflict with the aimed brand image.

While reusing the product for the same purposes is given in many cases, also when looking for the durability aspect, reusing it for different purposes depends strongly on the product's design. Often there is a need for consumer initiative and creativity expected. Communicating the possibilities of using the product in different ways is not actively done by the manufacturer. In addition, for the textile industry, it is seen as problematic to use products for different purposes, such as cleaning cloths, as it would reduce the ability to recycle the material afterwards.

Refurbishing or remanufacturing the products also raises some challenges. First is the product design. For example, once tableware is broken, it cannot be used in this cycle anymore and can only be disposed. Furthermore, bamboo can be quite fragile, depending on the product design. A small hit, on, for example, a lampshade, can damage the surface so much, that it cannot be refurbished anymore. Although for the lamps in particular, it could be an option to reuse the

electrical parts again, a lack of proof of concept leads to the assumption of being too costly.

In addition to the general product design that influences the ability to remanufacture or refurbish the products, there are challenges seen with the spare part availability. If the return date exceeds the length a product collection is available and manufactured, there are no possibilities to make use of the returned items for remanufacturing and refurbishing purposes. Overall, there is a lack of internal structure to implement such ideas.

However, the industry and market set up do play a role of the whether refurbishing or remanufacturing options are offered. For example, if a company decides to partner with other companies to refurbish or remanufacture its products, the market and industry might not able to provide this kind of services yet as no companies specialise in it, such as for lighting systems. Also, in the textile industry, it is much more a lack of internal motivation to implement refurbishing and remanufacturing options as they would reduce the overall sales volumes of new products in their currently new-product-sales-driven business models. However, even if a textile manufacturer is deciding to contribute to the cycle, it is necessary to gauge if consumers are willing to buy it. For undergarments, it is seen as unlikely that people would want to buy garments that contain remanufactured or refurbished materials from undergarments of an unknown person.

When looking at recycling and upcycling, the manufacturers see potential in it but also certain challenges. One of these challenges is the product composition. Any product that gets in contact with food, like for the single-use packaging or tableware, using recycled material with unknown origin and use conditions cannot guarantee to fully comply with food safety regulations. This goes contrary to the statement of INBAR (2019), that argues that bamboo waste is ideal for single-use products. For other products those use glue additives, like durable tableware, separating the glue from bamboo in the recycling process is seen as a challenge. This finding underlines the statement of McDonough and Braungart (2002) that fusing biological and technical materials together irreversibly, lead to losing the materials entirely for the cycles. Another element of the product composition is the strength properties. Despite it is possible to recycle garments in the textile industry, recycling bamboo multiple times will reduce the bamboo material strength. That leads to the need for additional synthetic yarns to keep the required strength, making the C2C idea of keeping the nutrients in a constant loop impossible. This confirms the criticism of Reay (2011) on the lack of consideration of the wearing out process in the Technosphere and of the ability to recycle synthetic materials.

However, even if there would be no issues with the product composition for the recycling process, there seems to be a lack of technology. For example, there is no machinery on the market that enables shredding the long bamboo fibre efficiently. This goes in particular for the furniture and construction and finishing materials.

Furthermore, the infrastructure needed for recycling its own products is seen as challenging. For example, getting the returned goods back to the factories

is seen difficult in particular for consumer items and textiles. If a manufacturer produces its products in Asia and is eager to foster the local economy by sourcing locally, but its main customers are in Europe, returning their products back to Asia for recycling may work against their commitments and may cause a higher environmental footprint than necessary. This greater environmental footprint shows parallels to findings of Vogtländer et al. (2010), addressing the superior performance of recycled European softwood in Europe over recycled bamboo material for MDF boards.

Next to the environmental component influenced by the recycling infrastructure, the actual returning process is also seen as a challenge in itself, as it requires an active role of the consumer. In particular smaller manufacturers with no physical store that possibly could collect old garments on-site need to rely on the consumer to send them back via mail, which is perceived as too much of an effort for consumers. Such logistical and operational challenges as stated by the manufacturers are confirmed by Nielsen and Brunoe (2015), who argue that getting the products back and forecasting the volumes creates difficulties in planning and scheduling manufacturing processes.

In addition to challenges with the product composition, the lack of technology and infrastructure for recycling, the manufacturer requires a certain quantity of returned textiles to break-even with such operations. Currently, such integrated systems, are seen as too expensive for the manufacturer's operations to make it profitable. The same argument is being made in the furniture industry.

Additionally, not only does the price sensitivity play a role in the feasibility of recycling materials, but also consumer preferences and the general set up of the industry and market. On the one hand, it is determined by consumer preferences, for example in the textile industry, where it is believed that consumers are not eager to purchase garments that potentially contain recycled undergarments. On the other hand, the industry itself lacks to offer an established market for recycled bamboo, for example for construction and finishing materials. The latter observation is also reflected in the stated critique of Bjørn and Hauschild (2013), who claims that C2C does not consider enough the current waste and energy infrastructure in the market and industry manufacturers have to deal with and addresses the third recommendation by van der Lugt and King (2019) to develop a more integrated bamboo industry.

5.3 Product of Service

In order to utilise the elements of the Technosphere successfully, C2C proposes an implementation of the PoS concept along with them. It is seen as a tool for managing the responsibility of keeping the nutrients in a closed-loop. However, as this concept requires a shift from a sales volume driven linear business model to a service-driven circular business model, it needs to be investigated whether

manufacturers see potential in this concept overall. Because it is part of the Technosphere, this concept addresses, along with the Material Reutilisation, the second sub-research question:

2. How applicable is the Technosphere to the manufacturers' products?

Similar to the Material Reutilisation, the applicability of PoS strongly depends on the manufacturer's perception of whether their products are suitable for such a business model or not. It seems that the longer the lifespan of the product and the resulting higher purchase price is, the easier it is perceived to implement or add PoS to their current business models in theory. For products that seem to have a shorter lifespan with lower purchase prices, the concept is seen as impractical. Potential is recognised in particular for the construction and finishing materials already, as there has been an active attempt in implementing it already. Overall, the perception of consumer's behaviour is essential on whether such natural products are seen as good products for this concept. Nevertheless, from a CSR expert opinion, this concept is the only way to make sure products are sustainable and durable, in particular for the textile industry.

Despite the relatively wide positive feedback on the concept itself and a certain confirmation of the applicability of it to their products, the manufacturers still see a lot of challenges with it. To address these, and to complement the material reutilisation, the third research question is addressed:

3. What similarities and differences can be identified for the manufacturers' challenges and needs with the principle?

The challenges and needs of the manufacturers are manifold. One of the challenges, that in particular applies to consumer items, is the product design. The general nature of consumer items is to be consumed and can be considered as having short lifespans. This makes such a leasing model extremely impractical and is perceived as too expensive to execute based on current sales volumes of the manufacturers. Financial concerns are also seen in other industries such as furniture and the textile industry.

Another challenge arises from the needed integrated systems, which, however, is lacking. In particular for the furniture and textile industry, operations of PoS are seen as highly resource-intensive. For example, frequently transporting rented products from A to B with dimensions similar to the wedding sheds can become a constant logistical obstacle. Also, the distance transported is seen as critical. For the textile industry, having the products manufactured in Asia and having customers in Europe, returning them to the manufacturing place is seen as inefficient. This business model would demand a shift of the manufacturing place closer to its customers to make it a more viable and sustainable option. Moreover, for this business model, product availability is seen as essential, which requires keeping a certain amount of stock in a warehouse. That can be a challenge in particular for smaller furniture manufacturers. Considering that

manufacturers are also unsure about the demand for such a service in their markets, plays a role for some manufacturers to not pursue this idea further.

Another challenge that also plays into the financial aspect is linked to the role of the consumer. There is the belief that consumers will not take good care of the product if they do not own the product themselves. This can be seen as a risk factor in particular for natural products such as ones made from bamboo canes that require more careful handling. With the idea of leasing the products and needing to give warrantees in form of maintaining and repair services on them, this business model is seen as being a potential loss-making business. This perception is contrary to the statement of McDonough and Braungart (2002) that PoS can create a better buyer-customer relationship due to closer ties and benefit from this relationship financially.

Although the role of the consumer is important for the PoS concept, the role of the manufacturer also is essential, in particular the manufacturer's motivation to implement such a concept is vital here, which has been addressed by the manufacturers with two challenges. The first is linked to the business structure. Although PoS has had a great reception for some manufacturers producing construction and finishing materials the manufacturers mostly market and sell imported products as a merchant to smaller retailers, resulting in no particular interest in implementing such a concept at all for some of the manufacturers. The second is the perceived image of PoS that may conflict with the brand image that the manufacturer wants to create. In the textile industry, applying the PoS concept can lead to the association with second-hand clothing, which may not be in the interest for brands intending to create a luxurious image. These concerns confirm the argument of Bakker et al. (2010) that, even if there might be a skilled designer to implement a C2C approach, such decisions are often made on a strategic management level.

5.4 Design Phase

Bamboo in itself has been described as having potential for CE and C2C can be a concrete concept that can be applied by manufacturers. However, this requires active considerations starting in the very beginning of the product, in the design phase. If the respective material potential is not recognised or the priorities are not specifically tailored to keep the nutrients in one of the spheres entirely, the extent of applying the principle is diminished. To investigate this aspect, the fourth sub-research question is looked at:

> *4. What intentions were present and missing in regards to bamboo and C2C during the design phase?*

Addressing the intentions of using bamboo as a raw material of the manufacturers were manifold. It ranged from the ecological aspects of being an alternative to wood and plastics to its ability to grow without pesticides and insecticides with ease. Its short-harvested time, the great availability and traceability, and its great versatility have been seen as reasons for choosing bamboo as a raw material also. The product story that bamboo is able to offer and the great fit for the company's mission and vision are also reasons mentioned. Next to these, personal experience with bamboo or their alternatives, as well as the general enjoyment of the work process with bamboo were critical factors for deciding for bamboo. However, market developments as well as identifying a specific market niche have also been reasons for developing bamboo products. Overall, the manufacturer's intentions were sustainability-driven and recognise the advantages bamboo offers in this area. However, none of them has specifically mentioned that bamboo has been chosen to facilitate a CE approach.

Looking more at the manufacturers' design phase, it is evident that this phase is determined by trade-offs, internal possibilities, and industry- and market conditions. All participating manufacturers have an intrinsic motivation to offer a more sustainable product. However, they are not necessarily approaching it in a circular way. Identifying problems with products in their industry and finding more sustainable alternatives to the status quo is done by every company. This can take different forms, those can be grouped into either what materials are used or how the materials are used.

In terms of how the materials are used, some manufacturers have designed their products in such a way that it is possible to transport them most efficiently, leading to CO_2 reductions. In this context, it can be said that the approach is more addressed from an LCA point of view that Bjørn and Hauschild (2013) as well as Bakker et al. (2010) described. Looking more into the construction and finishing materials as well as the furniture, the intentions for more sustainability have even led to touching on some of the vital aspects of C2C. For example, the number of refurbishment cycles has been considered in the design phase, determining the thickness of a product. Moreover, designing the product in such a way that it is easily assembled and disassembled is another important aspect of C2C as it can help to separate the biodegradable bamboo from other non-biodegradable components used (McDonough & Braungart, 2002). In terms of additional components, the manufacturers have applied this to a great extent.

In terms of what materials are used, some manufacturers try to ensure the sustainable quality of it through obtaining different certificates. In the textile industry, in particular, there is a trend to focus on raw material use and the production processes to improve the sustainable aspects. Nonetheless, the element of comfort is still a strong driver for manufacturers to choose a specific raw material and production process in this industry.

However, the greatest C2C conflict, in terms of what materials are used, is related to the manufacturers' practices of fusing biodegradable and non-biodegradable materials together in an irreversible way. According to McDonough

and Braungart (2002), this is called a monstrous hybrid and the material is perceived as useless for either of the two C2C spheres in the end. Looking at the practices of the manufacturers, apart from some products like the single-used packaging, table games, lamps, or products made from bamboo canes, the products have to rely on an irreversible fusion of bamboo with synthetic materials like resin, oils, lacquers or even hazardous substances for the production process.

The lack of consideration of this irreversible fusion is also partly reflected in the manufacturers' perception of what product category their products fall into. As C2C identified consumption products as 100% biodegradable, and all products containing non-biodegradable materials as service products (McDonough & Braungart, 2002), this product design approach is not applied in nearly all manufacturer cases. Only Company 3 with its biodegradable packaging and tableware was able to implement this approach. It is also the only manufacturer that actively engages with the C2C concept as they see great potential in communicating the sustainability aspect through C2C. This corresponds with the idea of Bjørn and Hauschild (2013) that C2C has the ability to communicate positive attributes.

6 CONCLUSION

This research explored to what extend the Cradle to Cradle principle 'Nutrients remain Nutrients,' can be applied by German and Dutch bamboo product manufacturers. The advantageous and sustainable properties of Bamboo have led to the realisation that this grass can play a vital role in replacing unsustainable raw materials. Because of its versatility, it finds application in many different industries for a great variety of products. This development attracted scientists to look at it further from a circular economy approach identifying opportunities and challenges. However, the circular economy is influenced by different concepts, one of them being Cradle to Cradle (C2C). C2C's first principle 'Nutrients remain Nutrients' requires a product categorisation into one of the metabolic cycles namely Biosphere and Technosphere. With the help of a strong emphasis on the design phase and consideration of the Product of Service concept for the Technosphere, a circular system shall be created. The lack of literature on bamboo in a C2C context led to the focus of this research to get a general understanding of the two together and what challenges and needs arise.

The research focus on Dutch and German manufacturers are based on the high numbers of bamboo imports and the great popularity of C2C in these two countries. Therefore, in total, 11 companies were interviewed on their take on the different elements of C2C in the context of their products. In the end, manufacturers in the industries of consumer items, construction and finishing materials, furniture, and textiles have participated, making it a broad spectrum of products. The data were coded first, then linked to C2C topics, and afterwards categorised into Material Health, Material Reutilisation, Product of Service, and Design Consideration. Finally, the coding process then allowed to identify emerging themes across all categories.

The results indicate that a generalisation based on solely the usage of bamboo as a raw material is difficult. Due to the great product variety and their different fundamental intended uses and requirements, great differences have been found even amongst manufacturers within one particular industry. However, one of the most prominent themes emerging from this research across all industries is the product composition. The intended use phase determines the needed shape, function, and durability. To provide optimal product use, oftentimes abiotic additives, like synthetic resins or lacquers, and additional components, like wires or metal joints, are needed. In particular products that require a high degree of durability look for better biodegradable glue alternatives, those are strong enough for the intended product use. Currently, only synthetic glues can offer the required strength, causing the C2C's unfavourable irreversible fusion of biotic and abiotic substances. Further, depending on the product, recycled materials may cause issues with food safety regulations. Moreover, opposed to the proposal in C2C, certain bamboo materials cannot be recycled indefinitely, such as

bamboo textiles, as they lose their strength properties every time it is being recycled.

Another theme that determines the viability of the principle is the product design in itself. If the product exceeds a certain size, it may be seen as difficult to share or trade the product between customers due to the logistical efforts. Moreover, the design of certain products, in particular consumer items, are designed for disposal, such as tableware that is not meant for repair or remanufacture. Apart from the last proposed cycles of recycling in the Technosphere, a similar conclusion can be drawn for textiles. Similar challenges also arise when a product is designed for a certain shape in mind. If the shape requires the bamboo to be thin, a refurbishing process is not possible. However, practices have also shown the opposite. Products were designed in a way that a predetermined number of refurbishment cycles determines the thickness of the product. Another element that C2C is emphasising is the disassembly of the product. To a great extent, the idea of easy assembly and disassembly of the product with additional components has been given, making it easier to separate the bamboo material from other abiotic components.

The next theme identified is linked to technology. The industries have the opportunity to choose suppliers with technology that enables closed-loop chemical collection processes, which goes along with the C2C principle's idea. However, the toughness of bamboo fibres remains a challenge. This not only leads to the need for new inventions for the textile industry to break down fibres to create yarn but also needs improved machinery to shred the long bamboo fibres, so the construction and finishing materials as well as furniture can recycle their own materials. This is also reflected in a lack of supply and demand for refurbishment services and recycled materials, in the theme of the industries and the markets.

Next to technology and industries and markets, suppliers and partnerships, are seen as essential. Opportunities and challenges have been identified in this field. For example, while some manufacturers have great experience with partnering up for end-of-life-cycle solutions as well as knowledge sharing and creating awareness on C2C, others struggle with a lack of supplier comprehension on general sustainability issues.

Furthermore, suppliers also partly feed into the next theme of infrastructure. The distance to the predominately Asian suppliers, in particular manufacturers of consumer items, make the recycling process difficult and may interfere with local sourcing commitments. Overall, manufacturers see great challenges with the needed infrastructure required. These concerns are related to transporting returned goods, storing the final goods for constant availability in a PoS business model, and forecasting the refurbishing, remanufacturing, or recycling demand and supply appropriately.

The C2C proposed infrastructure operations are seen as expensive leading into the next theme of cost-benefit-ratio. While repairing, maintaining, and refurbishing services are offered for some construction and finishing materials as well as furniture, repairing or maintaining consumer items or refurbishing additional components of furniture like lamps are seen as too expensive. Whether textiles

are repaired or maintained, is also seen as very price dependent, meaning the higher the value of the product, the more likely consumers are willing to get the textiles repaired or maintained.

Overlaps can also be found with the theme of the role of consumer/customer. Not only can the cost-benefit-ratio be drawn from a manufacturers' point of view, but also from the consumer/customer's point of view. While it is possible to dye textiles naturally and environmental-friendly, not every consumer/customer is willing or able to pay for the higher price tag. In addition, the desire for immaculate visual state and customisability such as special lacquers on natural products, the rejection of certain recycled materials such as undergarments, as well as motivation for returning products and the general product handling influence the extend of biodegradability, circularity, and applicability of leasing models like PoS. To achieve that, manufacturers see the need for customer education and general mindset shift on these issues.

However, also the role of the manufacturer is important, which is seen as the last theme identified. Although all manufacturers have an intrinsic motivation to contribute to sustainability with their products, it requires commitment to a new business model to apply the proposed circular approaches. If the circumstances are right, the results show that such an approach can be applied successfully. However, oftentimes, there is seen a lack of successful examples in the different industries to manifest the needed a commitment to breakthrough current practices and establish new ones with a new strategic direction. Currently, the responsibility of who needs to contribute to circularity is not solely seen on the manufacturers' site.

Overall, it can be concluded that the C2C principle can be a viable option for Dutch and German bamboo manufacturers if circumstances are right. This needs to be looked at on an individual basis. Current circumstances only allow applying certain elements of the Material Health and Material Reutilisation. The applicability of the PoS concept seems to be strongly influenced by the lifespan and price of the product, and, despite motivation for sustainability is given, circular thinking is diminished by trade-offs the manufacturers have to deal with.

6.1 Trustworthiness

In order to assure the reader the scientific nature of qualitative research, the concept of *trustworthiness* can be applied (Lincoln & Guba, 1985 as cited by Eriksson & Kovalainen, 2008). This concept proposes four criteria: credibility, transferability, dependability, and confirmability (Nowell et al., 2017).

According to Eriksson and Kovalainen (2008), a research is to be seen credible when the researcher has familiarised himself with the topic, the data provides logical links to identified categories, and that fellow researchers are able to come to similar a conclusion based on the research. For this research, the researcher has familiarised himself with bamboo as raw material and the concept

of C2C as well as both of their practical implications. Categories those have been applied to the data are based on concepts found in literature, providing a logical link to practical implications. Section 3 provides detailed information on the research methodology, data collection, and data analysis, allowing fellow researchers to construct a similar research approach with similar interpretations.

The degree of transferability of a research is determined by what connections can be found between existing publications findings and findings of the conducted research (Eriksson & Kovalainen, 2008). Looking at this particular research, and despite the lack of publications combining bamboo with C2C, similarities have been found between challenges and needs of bamboo and C2C provided in already existing publications, and challenges and needs participating manufacturers have expressed. These have been highlighted accordingly.

According to Eriksson and Kovalainen (2008), to ensure dependability, clear documentation, traceability, and applied logic have to be provided to the reader. For this research, Section 3 provides information on what grounds participants have been chosen, who has been interviewed in the end, and in what form for how long. It also provides information on the logic of how the data has been analysed.

Confirmability is addressing the degree of understanding of how findings and interpretations are based on the data (Eriksson & Kovalainen, 2008). Normally, this is automatically achieved when credibility, transferability, and dependability are fully applied (Guba & Lincoln,1989 as cited by Nowell et al., 2017). In this particular research, this has been achieved by describing the analysis process in Section 3.3. Also, with the help of providing the opinions of the manufacturers in Section 4, allows gaining an understanding what basis the analysis is subject to.

6.2 Limitations

Due to the scope and circumstances of this research, certain research limitations need to be addressed. First and foremost, it needs to be stated that, due to the wide range of products within the different industries, and the low number of participants in each industry, findings are not entirely representative for the whole industry, but solely provides an indication. Furthermore, this research is not representing the viability of the C2C principle based upon criteria used for C2C certifications, as this research was bound to resources and time constraints. It merely provides a general perception of the viability of the concepts. Moreover, this research failed to gather information on the pulp and paper industry, as well as others that utilise bamboo as raw material also, due to no interest in participating or no responses in the first place. Additionally, this research does not investigate similarities or differences between Dutch and German manufacturers in this context but treats them equally.

6.3 Further Research

As the findings indicate a great variety of challenges and needs across the different industries, it is recommended to have a greater focus on either a specific industry or, preferably, even a focus on a specific product. This would help to identify more tailored solutions for the manufacturers to incorporate the principle. For example, it could reveal more technical and material insights, such as the minimum requirements of biodegradable glues. In this context, it would be advised to conduct more tailored research on the construction and finishing materials industry, as, for example, achieving to replace synthetic glue for such the industry's high demand for durability and sturdiness would automatically benefit the furniture and consumer items industries, with lower durability and sturdiness demands. Furthermore, it would be advised to investigate what possibilities the Paper and Pulp industry offer in terms of the principle, as it was not able to find willing participants from this industry for this research. The increasing demand for packaging materials due to online sales becomes more important in today's world. Additionally, it would be interesting to see whether there are differences in the perception of the viability between Dutch and German manufacturers. This could reveal interesting cultural elements that may play a role in what approach is needed to foster this principle in companies. It would also be interesting to investigate what industry is able to comply with C2C easily. This could help to find possible alternative methods that could be able to be translated into one of the different bamboo industries. Moreover, as the PoS concept is seen as fundamental for products in a technical cycle, and the receptiveness amongst construction and finishing materials as well as furniture have been generally open, consumer behaviour should be investigated. The concerns that consumer/customers treat rented products worse than if they would own them, would require scientific backup in order to develop strategies accordingly. Additionally, it would be interesting to see what the level of understanding and considerations of circularity in the purchasing process amongst consumers/customers is. For example, the desire to customise bamboo products with lacquers and oils reduce the degree of biodegradability, leading to consequences. Revealing the degree awareness in this aspect would allow to also determine the degree of educational work manufacturers have to take on.

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APPENDICES

Appendix 1: Interview Questions – English

Bamboo Products in a Circular Economy - Questions

My name is Christoph Meier and I am doing my Master in *Corporate Environmental Management* at the University of Jyväskylä in Central Finland. Currently, I am writing my Master thesis with the focus on circular economy for bamboo products. With that work, I would like to figure out to what extent the principle *"Nutrients remain Nutrients"* of the Cradle-to-Cradle framework by Michael Braungart and William McDonough can be applied to bamboo products. This way, I would like to contribute to getting a better understanding on missing elements and provide a basis for further research on how to provide these missing elements. That could be helpful for various industries those are currently using or will be using bamboo as a raw material.

Below, you will find the questions that I will be needing for my analysis. Should you not be familiar with a concept or you have not given thought about certain aspects asked, a 'I do not know' answer is a valid answer. It will not limit me on conducting an analysis.

I would like to thank you already for your efforts and your time!

Please tick the applicable Yes- or No-box and answer the question, when given, below the ticked box in grey.

ANONYMISATION
Is it okay to record the interview?
- ☐ Yes
- ☐ No

Would you like your company to remain anonymous?
- ☐ Yes
- ☐ No

Would you, as a respondent, like to remain anonymous?
- ☐ Yes
- ☐ No

GENERAL INFORMATION ABOUT THE RESPONDENT
What position do you have within the company?

Have you experience with Circular Economy or even Cradle-to-Cradle?
☐ Yes
Can you briefly explain your background with it?

☐ No

PRODUCT INFORMATION
Can you briefly explain why you decided to use bamboo as a raw material?

How would you describe your product?
☐ Consumption Product
☐ Service Product
☐ I do not know
What makes it difficult for you to define it in either one of the categories?

As bamboo is a natural and renewable raw material, it has the best preconditions to be biodegradable. However, this biodegradability strongly depends on the manufactured product. As your portfolio is rather extensive, focusing on one or very few products would simplify things. Looking at the ***Product X*** *would be interesting. However, you can also give examples from other products groups.*

Please indicate at least one product you would like to refer the following questions to.
Product 1:
Product 2:
Product 3:
Product 4:
Others:

Would you describe the above selected product(s) as 100% biodegradable, with no synthetic or other environmental harmful chemicals content for the product used?
☐ Yes
What challenges did you face and how did you overcome them?

☐ No
What would you need to be able to produce your product 100% biodegradable?

There are other ways to preserve materials if they are not biodegradable. The following questions are addressing these ways. Please, refer your answers to your selected product(s) above.

Do you know if your selected product(s) is/are shared or traded between customers?

☐ Yes
How is this usually done?

☐ No
To what extent do you see potential here?

Do you offer maintenance or repair options for your product(s)?

☐ Yes
Could you briefly explain how?

☐ No
Why did you decide to not offer them?

Can your product(s) be reused in its original form for the same or different purposes?

☐ Yes
Could you name some examples?

☐ No
Why is that the case?

Can your product(s) be used for refurbishing[*1] or remanufacturing[*2] processes?

[*1]refurbishing: product is repaired, tested, verified, and resold by the manufacturer
[*2]remanufacturing: product is rebuilt with the help of reused, repaired and new parts by the manufacturer

☐ Yes
Who is involved in that process?

☐ No
Why is that the case?

Can your product(s) be recycled or upcycled, meaning the waste product will be transformed into a product of higher quality?

☐ Yes
Who is involved in that process?

☐ No
Why is that the case?

PRODUCT-OF-SERVICE
Often, Cradle-to-Cradle suggests the concept of Product-of-Service or Eco-leasing, meaning you would keep ownership of the products you manufacture and you only sell the service or function of your products.

What is your opinion on Product-of-Service in the context of your selected product(s) and what would you need assuming you would decide to implement this business model?

DESIGN CONSIDERATION
Cradle-to-Cradle puts strong emphasis on the design phase. Looking back on the different elements discussed in the previous questions, to what extent did you consider them during the design phase?

END
May I contact you for follow-up questions?
- ☐ Yes
- ☐ No

Would you like to receive the final thesis?
- ☐ Yes
- ☐ No

Do you have recommendations on other potential interview partners, who could provide further insights?

Do you have any other comments you would like to give?

I would like to thank you for your efforts, your time, and your trust! I hope to be able to contribute to a better understanding on the industry and hope more companies like yours will recognise bamboo as a viable option for doing sustainable business. In the meantime, it needs to be evaluated how bamboo can be optimised and utilised to the most.

Please save this document and send it back to me whenever it is convenient for you to: [email address].

You can contact me any time also via mobile on: [phone number].

Thank you very much!

Appendix 2: Interview Questions – German

Bambusprodukte in der Kreislaufwirtschaft - Fragen

Mein Name ist Christoph Meier und ich mache gerade meinen Master in *Corporate Environmental Management* an der Universität Jyväskylä in Mittelfinnland. Derzeit schreibe ich meine Masterarbeit mit dem Schwerpunkt *Kreislaufwirtschaft für Bambusprodukte.* Mit meiner Arbeit möchte ich gerne herausfinden, inwieweit das Prinzip „Nährstoffe bleiben Nährstoffe“ des Cradle-to-Cradle-Ansatzes von Michael Braungart und William McDonough auf Bambusprodukte übertragbar ist. Es soll daher ein Beitrag leisten für ein besseres Verständnis für fehlende Elemente und könnte Grundlage sein für weitere Forschung wie man diese fehlenden Elemente herbeischaffen kann. Dies könnte von Vorteil für mehrere Industrien sein, die Bambus als Rohmaterial derzeit verwenden oder in der Zukunft verwenden könnten.

Hier finden Sie die Fragen, welche ich für die Ausarbeitung benötige. Wenn Ihnen ein Konzept nicht unbekannt ist oder Sie sich über gewisse Aspekte noch keine Gedanken gemacht haben, ist eine „Ich weiß es nicht“ Antwort völlig berechtigt und schränkt mich nicht in meiner Analyse ein.

Ich möchte mich schon einmal herzlich bei Ihnen für Ihre Mühe und Zeit bedanken!

Bitte klicken Sie das auf Sie zutreffende Ja- oder Nein-Feld an und beantworten die Frage, falls vorhanden, unter dem angeklickten Feld in grau.

ANONYMISIERUNG
Ist es in Ordnung das Gespräch aufzuzeichnen?
- ☐ Ja
- ☐ Nein

Möchten Sie das Ihr Unternehmen anonym bleibt?
- ☐ Ja
- ☐ Nein

Möchten Sie als Befragter anonym bleiben?
- ☐ Ja
- ☐ Nein

ALLGEMEINE INFORMATIONEN ZUM BEFRAGTEN
Welche Position haben Sie in Ihrem Unternehmen?

Haben Sie Erfahrung mit Kreislaufwirtschaftssystemen oder sogar Cradle-to-Cradle speziell?

☐ Ja

Können Sie in wenigen Worten erzählen welche Erfahrung Sie hier haben?

☐ Nein

PRODUKTINFORMATIONEN
Können Sie kurz erklären wieso Sie sich für Bambus als Rohmaterial entschieden haben?

Als was würden Sie Ihre Produkte bezeichnen?

☐ Gebrauchsgut
☐ Service Produkt
☐ Ich weiß es nicht

Was macht es für Sie schwierig Ihre Produkte in das eine oder das andere einzuteilen?

Da Bambus ein nachwachsender und natürlicher Rohstoff ist, hat es die besten Voraussetzungen biologisch abbaubar zu sein. Das hängt allerdings vom hergestellten Produkt ab. Da Ihr Produktportfolio sehr umfangreich ist, wäre eine Fokussierung auf ein Produkt einfacher. In diesem Fall, wäre Ihr ***Produkt X*** *interessant für diese Studie.*

Würden Sie Ihr Möbel als 100% biologisch abbaubar bezeichnen, welches keine synthetischen Materialien oder andere umweltschädliche Chemikalien verwendet und während der Produktion ausstößt?

☐ Ja

Welche Herausforderungen hatten Sie hierbei und wie haben Sie diese überwunden?

☐ Nein

Was benötigen Sie um Ihr Produkt so herstellen zu können?

Es gibt aber auch andere Wege Materialen zu bewahren, sollten sie nicht biologisch abbaubar sein. Die folgenden Fragen beziehen sich genau auf diese. Bitte versuchen Sie hier ebenfalls die Fragen auf das ***Produkt X*** *zu beziehen.*

Wissen Sie ob Ihr Produkt unter den Kunden miteinander geteilt oder getauscht wird?

☐ Ja

Wie läuft das in der Regel ab?

☐ Nein

Würden Sie hier Potential sehen?

Bieten Sie auch Wartungs- oder Reparaturoptionen an?

☐ Ja

Können Sie diese ganz kurz erläutern?

☐ Nein

Weshalb bieten Sie diese nicht an?

Kann Ihr Produkt in seiner Grundform wiederverwendet werden, z.B. für denselben oder einen anderen Zweck?

☐ Ja

Können Sie Beispiele nennen?

☐ Nein

Warum ist dies der Fall?

Kann Ihr Produkt instandgesetzt werden oder wiederaufbereitet werden?

☐ Ja

Wer ist in diesem Prozess involviert?

☐ Nein

Warum ist dies der Fall?

Kann Ihr Produkt recycelt oder sogar upcycelt, sprich Ihr Abfall wird veredelt und zu einem hochwertigeren Produkt, werden?

☐ Ja

Wer ist in diesem Prozess involviert?

☐ Nein

Warum ist dies der Fall?

PRODUCT-OF-SERVICE
In gewissen Fällen schlägt der Cradle-to-Cradle Ansatz das Konzept „Product-of-Service" oder "Eco-leasing" vor. Hierbei bleibt das Produkt in Ihrem Eigentum und Sie verkaufen lediglich den Service oder die Funktion des Produktes.

Was ist Ihre Meinung zum Product-of-Service mit Hinblick auf **Produkt X** und was bräuchten Sie, sollten Sie sich für solch ein Geschäftsmodell entscheiden?

DESIGN BERÜCKSICHTIGUNG
Der Cradle-to-Cradle Ansatz legt einen großen Schwerpunkt auf die Designphase. Mit Hinblick auf die eben behandelten Aspekte, inwieweit haben Sie diese Aspekte während des Produktdesigns für das **Produkt X** berücksichtigt?

ENDE
Darf ich Sie kontaktieren für Nachfragen bezüglich Ihrer Antworten?
- ☐ Ja
- ☐ Nein

Möchten Sie die Ausarbeitung der Masterarbeit zugeschickt bekommen?
- ☐ Ja
- ☐ Nein

Hätten Sie evtl. Vorschläge für weitere potentielle Interviewpartner, die weitere Einblicke ermöglichen?

Haben Sie noch weitere Anmerkungen zu dem Thema?

Ich möchte mich ganz herzlich für Ihre Bemühungen, Ihre Zeit, und Ihr Vertrauen bedanken und hoffe, dass mehr Industriezweige Bambus als große Chance für ein nachhaltigeres Wirtschaften entdecken. Währenddessen muss evaluiert werden, wie Bambus besser optimiert werden kann.

Bitte speichern Sie das Dokument und schicken es, wenn Sie Zeit dafür haben, zurück an mich an: [E-Mail-Adresse].

Sie können mich auch jederzeit erreichen unter: [Telefonnummer]

Vielen herzlichen Dank!

Appendix 3: Interview Details

No.	Country	Industry	Company	Product Range	Respondent	Position	Interview Type	Date and time of Interview
Company 1	DE	Consumer Items	DeinBambuswald	Everyday products for office, kitchen, bathroom, etc.	Anonymous	Anonymous	Email	14 July 2020
Company 2	DE	Consumer Items	Pandoo	Everyday products for office, kitchen, bathroom, etc.	Anonymous	Anonymous	Email	29 June 2020
Company 3	NL	Consumer Items	Biofutura	Packaging material, disposable and durable tableware	Ekaterina Smid	Sustainability Consultant	GoogleMeet video call	04 August 2020, 10:10 – 10:50
Company 4	DE	Construction & Finishing Materials	GS Götz Schmitt	Decking boards, privacy fences, etc.	Götz Schmitt	Owner	Telephone call	31 July 2020, 11:00 – 11:30
Company 5	DE	Construction & Finishing Materials	Anonymous	Bamboo canes, fences, floors, panels	Anonymous	Owner	Telephone call	03 July 2020, 17:30 – 18:00
Company 6	NL	Construction & Finishing Materials	KOSA Bamboo	Frames, stairs, tables etc.	Koen Ottes	Owner	Zoom video call	06 July 2020, 15:15 – 15:45
Company 7	DE	Furniture	Bamboo-House.de	Wedding sheds, beds, chairs, tables, etc.	Joost Marienhoff Ingo Schetzberg	Owners	On site visit: Hengstforde 9, 26607 Aurich, Germany	19 June 2020, 09:30 – 12:00
Company 8	NL	Furniture	Anonymous	Lightning	Anonymous	Key Account Manager/ Marketing & branding	Zoom video call	19 June 2020, 14:30 – 15:10
Company 9	NL	Furniture	Bloooms	Tables, chairs, sofas, shelves, etc.	Paul Bloemers	Owner	Email	09 August 2020
Company 10	NL	Textile	Anonymous	Underwear	Anonymous	CSR advisor	Zoom video call	22 June 2020, 09:00 – 09:30
Company 11	NL	Furniture	Nooboo	T-shirts, sweaters	Amar de Winter	Owner	WhatsApp call	31 August 2020, 12:40 - 13:25

Appendix 4: Overview of Coding

Topic / Industry	Consumer Items	Construction & Finishing Materials	Furniture	Textiles
Product Category	Consumer Good Consumption Product	Construction Material Raw Material B2B Product	Customer's definition Consumer Durables Consumption Product	Consumption Product Present to Oneself Product of Brand Identification Community
Why Bamboo as Raw Material?	Plastic Reduction Fast Harvest No Pesticides and Insecticides Market Developments Mission and Vision	Versatility Educational Background Experience Market Niche	Tracability Work Process Ecological Aspect Versatility Availability Wood Alternative Bad Experiences	Wearing Properties Product Story False Claims
100% Biodegradable	Additional Components Additives Certification CO2 Compensations Measures Purchase Conditions Independent Testing Supplier Audits Supplier Comprehension	Additional Components Additives Product Dependent Positive Future Outlook Treatment Process Application Environment Consumer Preferences	Additional Components Additives Assesmbling Consumer Preferences Application Environment	Additives Buying Behaviour CO2 Compensations Measures Certification Chemical Collection Process Lack of Technology
Shared or Traded?	Ownership Reducing Interest of Product End of Life Cycle Focus	Unknown Consumer Initiative	Product Size Advertisement Business Model	Consumer Preferences Consumer Initiative
Repaired or Maintained?	Uncommon Practices Cost-benefit-ratio End of Life Cycle Focus	No Contact with Enduser Care Products Consumer Initiative Sanding & Lacquour Constructive Weather Protection Consumer Education	Customer Demand Infrastructure Dependent Consumer Education Cost-benefit-ratio Cleaning Agents Unknown Durability	Lack of Customer Motivation Product Price Dependent Consumer Education Lack of Industry Motivation Brand Image Resource Intensive
Reused?	Long Lifespan Consumer Creativity Addressed End of Life Cycle Focus	Limited Possibilities Weathering Degree Dependent	Product Flexibility Product Design Customer Communication Material Choice	Recycling preferred Consumer Initiative
Refurbished or Remanufactured?	Unrepairable Consumer Initiative End of Life Cycle Focus	Consumer Initiative Sanding & Lacquour	Work Location Manufacture's Responsibility Material Properties Industry Services Internal Structure Financial Aspect Spare Part Availability Material Choice	Consumer Preferences Lack of Industry Motivation

Topic \ Industry	Consumer Items	Construction & Finishing Materials	Furniture	Textiles
Recycled or Upcycled?	Additives	Consumer Initiative	Price Sensitivity	Lack of Customer Motivation
	Cost-benefit-ratio	Lack of Technology	Integrated System	Transportation
	Food Safety	Questioning Necessity	Additional Components	Quantity of Returns
	Waste Stream Material	Waste Stream Material	Lack of Technology	Financial Aspect
	Local Sourcing	Lack of Industry Services	Supplier Communication	Strength Properties
				Consumer Preferences
				Technical Feasibility
Product of Service	Cost-benefit-ratio	Execution Attempt	Transportation	Seen as Essential Concept
	Inadequate Product type	Unknown Market Potential	Cost-benefit-ratio	Theoretical Interest
	Partnerships	Positive Future Outlook	Positive Future Outlook	Lack of Infrastructure
		Lack of Manufacture Interest	Increasing Costs	Manufacturing Location
			Poor Product Handling	Brand Image
			Resource Intensive	Unknown Demand
			Product Availability	Price Sensitivity
			Unknown Demand	
			Warrenty Concerns	
			Integrated System	
Design Consideration	Trade-off	Assembling	Avoidance of Traditional Materials	Lack of Circular Thinking
	Certification	No active consideration	Transportation	Raw Material Focus
		Number of Refurbishment Cycles	Integrated System	Industry Focus
		Market Niche	Disassembility	Intrinsic Motivation for Sustainability
			Problem Identification	Fibre and Dye Properties
			Intrinsic Motivation for Sustainability	Industry Services
Cradle to Cradle	Knowledge Partners			Chemical Collection Process
	Feasibility support			Production Process
	Creating Awareness			Material Properties
	Sharing Knowledge			
	Cost-benefit-ratio			

Legend of Themes	
Product Definition	Suppliers & Partnerships
Product Composition	Industry & Market
Cost-Benefit-Ratio	Infrastructure
Role of Consumer/Customer	Technology
Role of Manufacturer	Product Design