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THE CRADLE TO CRADLE (C2C) PARADIGM IN THE CONTEXT OF INNOVATION MANAGEMENT AND DRIVING FORCES FOR IMPLEMENTATION

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Abstract

In the light of depleting natural resources and growing awareness for responsible consumption, "Cradle-to-Cradle" (C2C) has emerged as one of the key concepts redefining product characteristics and assigning a new role to environmental responsibility of companies. It reframes the general goal of reducing negative externalities in a more positive way seeking the design of healthy products made out of benign materials that circulate in an endless flow of resources after the use phase. The importance of the relatively new paradigm, coined by the chemist Braungart and architect McDonough, opens up new opportunities for companies and is already well established in practice. Considering the limited coverage of the topic in academia, especially in the context of innovation management, we aim to investigate the potential intersections between C2C and the Fuzzy Front End theory. Based on a case study research and a descriptive analysis of a dataset containing C2C certified products, we apply FFE success factors to C2C and derive enablers for successful C2C implementation.

Keywords: Cradle-to-cradle; eco-effectiveness; fuzzy front end

1 Introduction

Introduced through the book "Cradle to Cradle – Remaking the way we make things" by the German chemist Prof. Dr. Michael Braungart and American architect William McDonough, the new paradigm opposing the "Cradle to Grave" idea has echoed profoundly in different industries and countries (Bjørn, Hauschild, 2013). Growing customer awareness for sustainable products, healthy materials and responsible consumption has also raised the issue of a new imperative in environmental efforts that go beyond the current sustainability activities from the customer and practitioner perspective. The new design concept Cradle-to-Cradle (C2C) suggests answers and concrete steps to create products with positive effects instead of reduced negative externalities. C2C leads to an endless use of resources and ultimately results in a circular economy (Braungart et al. 2006). To be able to respond to certain product specifications, the main area of influence-taking lies in the very early stages of the innovation process. The later requirements are incorporated in the product development process the higher the cost (Herstatt, Verworn 2007; Khurana, Rosenthal 1998; Koen et al. 2002; Wheelwright, Clark 1995). When establishing C2C in this phase all toxic substances need to be eliminated, new substitutes defined and customer requirements considered. A very similar issue and phenomenon has already been investigated profoundly in the scholarship of Fuzzy Front End (FFE) in the innovation process.

In the presented work, we combine the C2C concept with the results of different studies on FFE success factors and FFE as a driver for innovativeness. After a descriptive analysis of the academic research state in the C2C area as well as a brief introduction in the concept of Fuzzy Front End, a two-fold research approach is applied. Beginning with an analysis of the C2C implementation level in practice, a set of companies that hold C2C certificates is subject to a descriptive analysis. In total, we examined almost 140 companies and 400 products. The second part of the investigation comprises of two case studies, the Dutch carpet manufacturer Desso and the US-based office furniture manufacturer Herman Miller, aiming to lay open which driving forces enable successful C2C implementation. The analyses aim at understanding the relevance of the fuzzy front end in the innovation process for successful C2C implementation. Furthermore, we examine how far empirical evidence about success factors of FFE management can be transferred to the new and empirically weak C2C area. The results corroborate the assumption of a definite link between C2C and FFE. Success factors that affect the FFE optimization also contribute to a successful implementation of C2C.

Major findings show the importance of a constant C2C endorsement by the top management in order to overcome potential barriers when starting C2C adoption. Moreover, the cases prove the need for appropriate expertise and appliance of advanced technology when implementing C2C. Due to the newness of the C2C concept, it is especially the expertise that demands partnering and alliances. Not only suppliers critically impact on the realization of C2C as they have to disclose information on materials and their characteristics. Other external partners are also included by the company in order to specify product requirements or give advice on potential material substitutes as well as resolve design issues. Following the first insights from this paper, a quantitative analysis should investigate more concretely how C2C integration in the FFE can foster success of C2C product launches and contribute to a longterm C2C establishment within a company.

2 Theoretical background

The cradle-to-cradle (C2C) paradigm presents a new perspective for the design and development of products and services and can be seen as the conceptual counterpart to the cradle-to-grave concept, which underlines the take-make-waste economy. "Cradle-to-cradle design enables the creation of wholly beneficial industrial systems driven by the synergistic pursuit of positive economic, environmental and social goals." (Braungart et al. 2006, p. 7). Ultimately aiming at eco-effectiveness, the C2C concept suggests changing products and services in a way that the associated material flows contribute to healthy and benign products (Braungart et al. 2006).

Besides the healthy material composition, another main component of the C2C concept is the formation of two metabolisms (cycles) that are fed by either biological or technical nutrients. According to their ability to be integrated in one of the cycles, all materials and product components need accurate selection prior to production (Braungart et al. 2006). The biological metabolism involves biodegradable, i.e. compostable materials, which can be natural or plant-based and are sold to the customer as nondurable goods of consumption (Braungart et al. 2006; Braungart, McDonough 2011). Examples are products that are biologically, chemically or physically changed by the customer, such as shoes, textiles, brakepads, etc. (Braungart, McDonough 2011). The technical metabolism applies to durable service products that are not biodegradable and need disassembly after their return from the customer. Instead, the aim of this cycle is to decompose the product components in such a way that all materials can be endlessly reused in new products over and over without losing quality and eventually even gaining intelligence through their constant appliance (Braungart et al. 2006). There are prominent examples for the technical metabolism from different office furniture manufacturers (e.g. Herman Miller or Steelcase), but also carpet fibers, televisions, etc. (Braungart, McDonough 2011). Three main tenets of the C2C concept specify the basic ideas for C2C implementation. The first principle "waste equals food" follows the principles of natural cycles. Hence, every kind of waste needs to be regarded as a nutrient that follows the technical or biological metabolism. Secondly "Use current solar income" specifies energy use to be location-specific in order to leverage natural and regional energy flows, including solar, wind and water. The third pillar "celebrate diversity" comprises creative and customized solutions instead of "one size fits all" solutions, e.g. renting of washing machines with a customized detergent that fits the local water characteristics (McDonough et al. 2003).

Especially the last example addresses a redefinition of goods that a customer purchases into a product of service, which allows the purchase of the needed service instead of the product. Ideally, it is the manufacturer who keeps ownership of a product from the technical cycle without selling it to the customer, which means that products become rather products of service than of consumption, also known as product service systems (PSS). This increases the planning reliability for a manufacturer. Furthermore, Hanssen revealed after an extensive case study analysis that PSS are more efficient when it comes to energy and material consumption (Hanssen 1999; Tietze et al. 2013).

Based on these main characteristics, the difference to the more commonly known concept of eco-efficiency becomes clear. Eco-efficiency "is achieved by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life-cycle to a level at least in line with the earth's estimated carrying capacity" (World Business Council for Sustainable Development 2000). Hence the aim is to maintain or increase a product or service value while at the same time reducing the needed resources and negative externalities (Huesemann 2004). Based on this idea, eco-effectiveness breaks with the common concept of decreasing negative externalities and formulates a positive action that aims for a "transformation of products and their associated material flows such that they form a supportive relationship with ecological systems and future economic growth" (Braungart et al. 2006, p. 2). By the shift from efficiency to effectiveness, Braungart and McDonough emphasize the need for a redefinition of waste as it is not the externalities per se that are harmful but their quality (McDonough, Braungart 2013; Bjørn, Hauschild 2013). Figure 1 illustrates the paradigm shift moving from reducing harmful activities to creating healthy products.

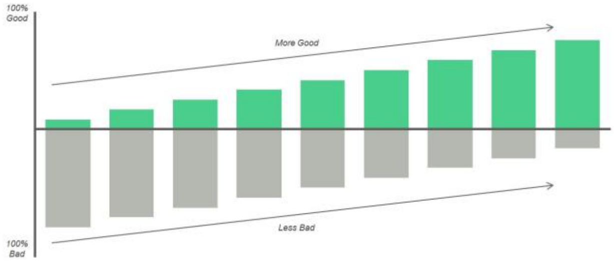

Figure 1: Moving from eco-efficiency to eco-effectiveness through cradle-to-cradle design (illustrated after McDonough, Braungart 2013)

To shed light on the state of research on cradle-to-cradle in the context of innovation management, we investigated the academic landscape based on the research database Web of Knowledge (Webster, Watson 2011). Starting by a combined search of the two strings "cradle-to-cradle" in the field TITLE and "innovation" in TOPIC, we received 5 results only. Thus, we broadened the research scope and analyzed the publications corresponding to the search string "cradle-to-cradle" in the field TOPIC without further specifications[1], which resulted in 102 publications, out of which only journal publications and book chapters that were clearly topic related remained in our final set of 56 articles and 13 book contributions. Looking deeper into the journal publications, we discovered that the state of the research, especially in the well-recognized academic papers, was limited compared to the number of practice-oriented articles. The publications in A, B-, or C-ranked journals (based on the 2011 VHB ranking of the German Academic Association for Business Research[2]) counted 8 out of 56. Out of these, 2 articles were published in the Journal of Industrial Ecology and 2 in the Journal of Cleaner Production. The other high rank

[1] The analysis was conducted on June, 26th – 28th 2013. The number of research results may have been subject to changes since then.

[2] Further information on the VHB Jourqual in: Schrader, U. and T. Hennig-Thurau (2009). "VHBJOURQUAL2: method, results, and implications of the German Academic Association for business research's journal ranking." *BuR–Business Research* 2(2): 180-204.

journals had published one C2C-related article only. The total number of 48 journals underlines the very fragmented base of C2C publications. The geographical coverage shows the highest percentage of publications (over 30%) originating from the US. The Netherlands places second with 13% of all publications. Germany contributes with 4% of publications in books or journals.

Further analyses of the dataset also revealed the newness of the topic to the academic field. Publications didn't start until the late 90ies. Besides their prominent and successful book publications, McDonough and Braungart contributed to the research with several papers, two of the most cited ones being the early article from 2003 "Applying the principles of green engineering to cradle-to-cradle design" published in Environmental Science & Technology as well as the widely acknowledged journal publication "Cradle-to-cradle design: creating healthy emissions - a strategy for eco-effective product and system design" from 2006 in the Journal of Cleaner Production. Besides the high relevance of the topic for chemical or health care researchers, the phenomenon has especially raised interest in related areas such as Reverse Logistics or Life Cycle Assessment. These discussions contributed to a critical analysis of C2C in the business area.

Looking at the advantages of the C2C paradigm, one major novelty resides in the formulation of positive actions replacing the discussion about what not to do, what to avoid and where to reduce. C2C opens up a new freedom for companies to think about positive externalities and product characteristics and how to develop goods or services that are beneficial for humans and the environment (Bjørn, Hauschild 2013; Braungart et al. 2006; McDonough, Braungart 2002; Senge 2008). For example, the Dutch carpet manufacturer Desso developed a carpet material that contributes to better air quality compared to other carpets and hard floor. Desso promises a reduced pollution with fine particles of eight times lower due to the C2C materials[3]. Especially in the office environment where air quality is poor due to electronic devices, closed windows, toner particles, etc. the C2C floor covering indicates the substantial potential of eco-effective products (Gou, Lau 2012). Such examples together with other prominent success stories create a very motivating momentum and enthusiasm that not only affects manufacturers and consumers but also engages a dialog between different parties such as players from the public sector, policy makers, researchers, companies and all kinds of professions like designers, architects or chemists. Within a company's value chain, C2C contributes to a more transparent dialog between the players along the supply chain (Pluijm et al. 2010; Senge 2008; Bjørn, Hauschild 2013).

Despite the benefits, cradle-to-cradle is also subject to skepticism. One main area of critics is the underlying assumption that energy efficiency is not necessary due to the use of renewable energy sources. While the theoretical concept might hold true for an ideal case of sufficient renewables capacity, reality gives cause to question this assumption. The negligence of energy efficiency in the C2C concept, e.g. mirrored in the certification criteria that do not clearly stipulate a 100% use of renewable energy sources, indicates that the effort of managing the biological or technical cycle might cause higher energy usage than current concepts, e.g. recycling (Bjørn, Hauschild 2013; Reay et al. 2011). Moreover, decomposition might not be possible for some products without a very high energy effort or because some materials need composition in order to satisfy product requirements (Bjørn,

[3] The product is called DESSO AirMaster®. More information is available at: http://www.dessoairmaster.com/en/home/b2b/

Hauschild 2013). In the automotive industry, for example, certain material composites ensure a lighter weight, which in turn results in lower fuel consumption. One other critical factor is based on the recent start of C2C implementation in practice. Not many suppliers can partner yet with a company according to C2C principles due to the high effort to analyse and lay open the full spectrum of material components. Only few suppliers are willing to disclose all the information and take the effort for only one producer (Rossi et al. 2006).

This calls for a more thorough balance between the state of the art technologies for product design and the C2C assumptions, which might actually hinder innovation when fully banning certain designs or procedures (Schmidt et al. 2004; Song et al. 2009). The focus on supplier management also underlines the importance of a very thorough planning before the actual product prototyping begins. To make C2C cycles work and succeed C2C implementation, there is a need for increased attention in the early phases. Enforced by the fact that combined research between the early phases of innovation and C2C is limited, the concept of Fuzzy Front End is introduced in the following.

Fuzzy Front End of Innovation

The concrete determination of the predevelopment phases often varies with the respective authors. Summarizing the main characteristics that are widely acknowledged, the Fuzzy Front End of Innovation (FFE) contains the activities from the initial product idea up to the decision to start the product development process, implying the commitment to release dedicated resources (Herstatt, Verworn 2007; Koen et al. 2001; Khurana, Rosenthal 1998; Cooper, Kleinschmidt 1991).

There is common accordance about the importance of the predevelopment activities highlighting this phase of the innovation process as a distinguishing feature of successful innovative firms with a more proficient performance (Cooper 1988; Cooper, Kleinschmidt 1991; Herstatt, Verworn 2007; Koen et al. 2001). These stages are important as they determine the full project set up, including planning of resources, timeline and quality targets which significantly influences the remaining project phases (Khurana, Rosenthal 1998; Koen et al. 2002; Khurana, Rosenthal 1998). Despite the consent on the importance of the front end activities, companies often lack a concrete definition of these phases and are not clear about the terminology. Especially when no concrete decision gate exists like suggested by Cooper, the line between the front end and the development process cannot be clearly drawn (Cooper 1988).This fact also contributes to the challenge of empirical work in this field and increases the number of theoretical or explorative studies (Khurana, Rosenthal 1998; Koen et al. 2001; Zhang, Doll 2001). Despite the lack of an established clear terminology, the importance of FFE urged numerous scholars to investigate success factors of FFE management. This leads to a valuable set of insights that allow a deeper analysis of a company's early innovation phases. Especially the work of Koen et al. (2002) with regards to the new concept development during front end stage has shed light on the most influencing success factors for FFE management. Three key components of the FFE were determined: The active driving role of leadership, culture and business strategy, the control of the activities from opportunity identification to concept definition as well as the consideration of influencing factors, such as organizational capabilities, the outside world and enabling technologies (Koen et al. 2002). Out of these, we decided to focus on the factors that enable the very first steps of C2C establishment in a company, which is new to the concept: Senior Management Involvement, Technology and Capabilities as well as Alliances and Partnerships. These areas shall provide a deeper understanding of concrete C2C enablers and are described in more detail in the following section.

While a substantial amount of effort should be in the front end where the effects on the innovation process are high, the attention and involvement of senior management as decision maker often increases only in the course of time and with proceeding stages in the product development process. Wheelright and Clark (1995) describe this phenomenon, illustrated in figure 2, as attention-influence mismatch. The consequences are higher costs as the possibility to influence the outcome decreases in the later stages and potentially product launch failures, e.g. due to missed specifications of the market (Cooper 1988; Khurana, Rosenthal 1998; Koen et al. 2001; Specht, Beckmann 1996)

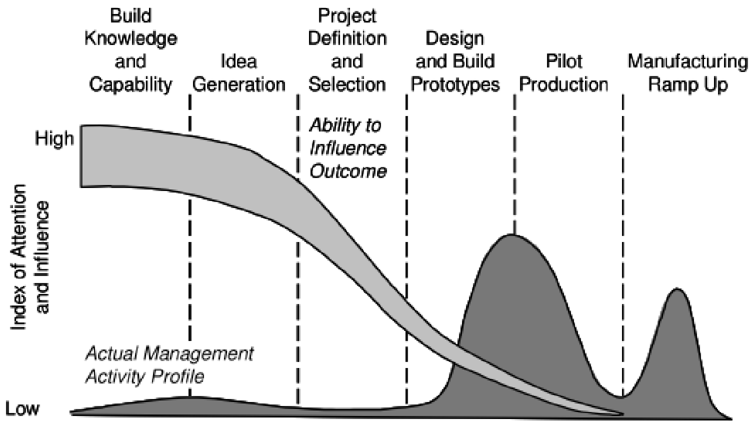

Figure 2: The attention-influence mismatch during the innovation process (Wheelwright, Clark 1995)

For this reason, many concepts exist to include the senior management as early in the innovation process as possible and continuously seek support from them as key decision makers throughout the fuzzy front end phases. This also facilitates resource allocation in the early phases and positively impacts the strategic fit of the new development project to a company's business (Cooper 1988; Cooper, Kleinschmidt 1987; Koen et al. 2002; Wheelwright, Clark 1995).

The proprietary capabilities of a company and the enabling technology are also crucial for the successful management of the fuzzy front end. Koen et al. (2002) specify "enabling" to be a technology that can be applied routinely by a company, meaning that this kind of technological skill contribute to higher quality achievements while cost are reduced (Koen et al. 2002).

Characterized by its fuzziness, the front end implies an uncertainty in different areas. Building alliances or partnerships in order to leverage knowledge can be critical for opportunity identification and the management of the early phases. The partnering can go from cross-functional teams within the company to manufacturer-supplier relationships, research alliances, coopetition or collaborations between the company and its customers (Cooper 1988; Von Hippel 1988; Koen et al. 2002; Wheelwright, Clark 1995). On the one hand, a company can benefit from the very early inclusion of customer needs, e.g. through engaging lead users, which is critical in the early design phases of the FFE. On the other hand, such alliances also foster creativity and problem-solving skills during the front activities while leveraging every participating partner's expertise.

Building on the presented success factors, the accordance of a company's innovations with external pressure and requirements is very important, e.g. government policies, regulations or legislation (Carrillo-Hermosilla et al. 2010; Byggeth, Hochschorner 2006; Koen et al. 2002). The environmental impact is heavily determined during the fuzzy front end of the innovation process. When products require certain specifications, it is necessary to set the basis in these early stages. Otherwise, it might be too late to implement certain features once the development process has advanced. This is where the importance of FFE for the cradle-to-cradle concept comes into effect. As a result, we combine the FFE theory as a less developed area of the innovation process with the C2C paradigm in order to understand and investigate potential success factors for implementation and typical enablers during the early phases.

3 Research approach

Braungart and McDonough co-developed with a number of leading companies a certification standard, which a non-profit organization under the leadership of an independent board of directors administers (C2C Products Innovation Institute). To examine the state of practical C2C implementation, we selected the set of products that hold a C2C certificate. Companies that are interested in obtaining the certificate have to employ an independent accredited assessment body from a selected list, which then analyses the product based on the C2C Certified Product Standard. The grades Basic, Bronze, Silver, Gold or Platinum can eventually be achieved (McDonough, Braungart 2013). The products are assessed through five categories; product and material health, product and material re-utilization, renewable energy, water used at manufacturing facility and social fairness (Braungart, McDonough 2011). The total cost of a certification is not publicly available. There is a fixed amount payable to the Institute, which is accessible on the website, however additional fees occur depending on the product to be certified. We created a database containing all products and the respective company currently holding a C2C certificate[4]. The analysis results are based on the certification status in November 2013, some minor changes in the product and company list have incurred since then.

The total set consists of 148 companies with C2C certificates for almost 400 products across different industries, implying business-to-consumer and business-to-business goods and services. Over 90% of the included companies are incumbents that operate in their market for at least over 8 years, the main part for more than 20 years. Looking closer at the company profiles, many are technology or innovation leader in their market, e.g. Alcoa[5], a global innovation leader in lightweight metals, products and solutions and established 125 years ago. Another example is Trigema, a German textile manufacturer producing in Germany for over 90 years[6].

There is no clear indication for one specific type of industry and products reach from baby strollers to fully re-usable building bricks. Goods in the area of interior design, including wall and floor coverings, make up almost 40% of the certificates, but also building materials, paper and packaging, personal and home care as well as textile and fabrics represent C2C covered areas. Examining the certificate level, we can see that products from the sectors of building materials (e.g. mushroom insulation material) and personal and home care (e.g. a replenish bottling company for household cleaners) make up more than 60% of the Gold certificates, which only represent about 10% of all certified products. Currently, no product holds the status of a Platinum certificate.

The descriptive examination of C2C certified products especially addresses the issue of a C2C rollout across the full product portfolio of a company. Based on the current dataset, we can see that the certified products per company vary from only one to almost 40, disregarding the company size. To derive enabling circumstances for C2C implementation in the company environment over a longer time period, we

[4] Products can be browsed at: http://www.c2ccertified.org/products/registry

[5] See detailed homepage at: http://www.alcoa.com/global/en/home.asp

[6] See detailed homepage at: http://www.trigema.de

investigate two examples of successful C2C rollout across different products.

Case Study Research

As discussed earlier, the empirical knowledge on C2C is rather limited, hence a case study approach was chosen in order to analyze more profoundly anecdotal evidence on C2C enablers and answer questions addressing "How" and "Why" issues with regards to implementation (Eisenhardt 1989; Yin 2009).

The specific cases of Desso and Herman Miller were selected based on the progress of C2C implementation and the C2C history within the respective company. The availability of information was also a selection criterion.

Desso is a leading manufacturer of high quality carpets and artificial grass pitches. The company, founded in 1930 and headquartered in the Netherlands, operates in more than 100 countries and serves both private as well as business customers. In 2008, after buying out the company in 2007, the management initiated C2C implementation as the first carpet manufacturer in Europe and set its goal to certifying all Desso products with C2C by 2020, thereby pushing C2C as a core vision statement (Braungart, McDonough 2011). "We want to be the world leader in making environmentally responsible flooring products that deliver outstanding value in design and functionality and thus contribute to people's health and wellbeing"[7]. In several interviews and statements, it becomes very obvious that the CEO (until 2012), Stef Kranendijk is a key ambassador of the C2C concept. He is convinced that "the fantastic thing about Cradle to Cradle is that it's all about innovation" (Crainer 2012). Inspired by a video on C2C and after reading Braungart's and McDonough's book, he contacts the authors directly to start a collaboration. In addition, he creates the position of a sustainability director and appoints Rudi Daelmans to assess all existing initiatives and progress work on C2C (Crainer 2012).

C2C efforts and main milestones

To date Desso holds numerous certificates for different products and has gained high attention, e.g. for their awarded innovation "Desso AirMaster", a carpet that filters particulate matter (fine dust) from the air and ameliorates air quality. Another key project in the context of C2C implementation is the take-back program that aims at managing the end-of-life phase of used carpets. Customers can return old carpet tiles, irrespective of their original brand, to Desso where the materials are decomposed and further processed for different purposes, e.g. the substance used for carpet backings, bitumen, is sold to road or roofing industries while used yarn can be re-used in Desso's own plants (see figure 3). In order to handle the recycling process of different materials from different manufacturers, Desso developed the separation technique "Refinity" to separate fibres from the backing of the carpets. After several investments in plants and new technologies, today Desso uses 100% recycled yarn in 60% of their sold products (Crainer 2012). One important milestone for the development of these programs was an EU subsidy in form of the "eco-innovation funding scheme."[8] In order to work against the C2C target Desso sets clear milestones and works closely and constantly with the Environmental Protection Encouragement Agency (EPEA). Concrete actions are the result, e.g. the recent installation of 23.000 m2 of solar panels on one plant in Belgium contributes to achieving the target of using exclusively renewable energy by 2020 (Crainer 2012). Furthermore, the effect of the different C2C efforts already pays off with economic benefits. Desso's EBIT has increased

[7] Source: http://www.desso.com/about-desso/vision, access date 30.01.2014

[8] Source: http://www.desso.com/c2c-corporate-responsibility/eu-eco-innovation-funding/, access date 30.01.2014

from 1% in 2006 to 9% in 2011, which again helps in convincing stakeholders to participate in the adoption of C2C. Another positive effect was the reduction in energy consumption of 50% from 2007 to 2011, which is facilitated by the increased use of green electricity (Crainer 2012)[9].

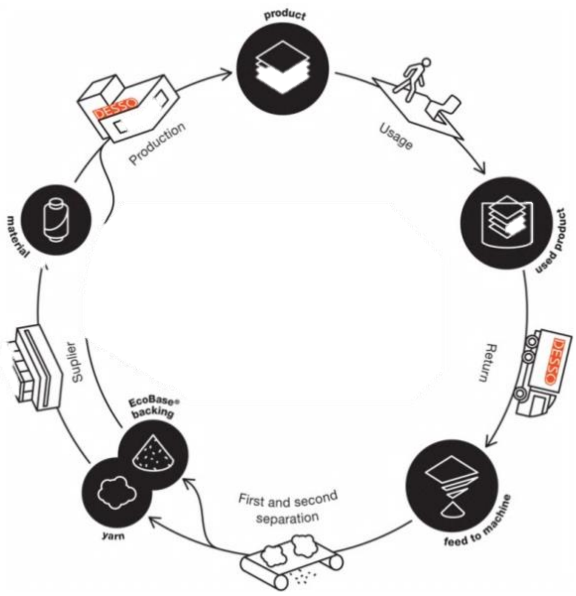

Figure 3: The technical cycle of Desso's Take Back and Refinity Program (EPEA Hamburg (http://epea-hamburg.org/de/case-studies/desso-0)

Benefits and challenges

The concrete implementation of C2C however is challenging and a long-term effort. Analyzing every single substance and material used in a Desso carpet tile is time-consuming and equires transparency and commitment from all involved parties. Supplier cooperation is key to assess all ingredients and production processes. For this reason, Desso accurately selects its supplier base and demands them to sign and comply with the product declaration forms they have developed for each raw material item.[10] Subject matter experts, from chemical or technological areas contribute to the redefinition of processes, substitution of toxic materials and the setup of new technologies, e.g. for the decomposition of used carpet tiles (Braungart, McDonough 2011; Crainer 2012). Involving customer needs and requirements is also needed for a successful C2C implementation (Carrillo-Hermosilla et al. 2010; Crainer 2012; McDonough, Braungart 2013). In Desso's case for example, the toxic free carpet tiles fostered business with the aviation industry where customer needs force companies to invest in air quality in the plane (Ellen McArthur Foundation 2012). Improvements in quality through C2C are also underlined in our interview with Desso's Director of Sustainability, Rudi Daelmans: "Cradle to Cradle gave us the insight, the awareness of the opportunities of increasing our qualities". In addition to quality improvements, the transfer into a circular economy allows for decreasing cost in raw material in the long run. Taking the example of Desso's innovative carpet tile backing, which is not toxic and can be fully recycled without loss of quality, the needed resources for extracting and re-using the materials are significantly lower than acquiring new raw material.[11] In the interview Daelmans the opportunities and challenges become very clear "Yes, the whole implementation of Cradle-to-Cradle increased our quality but to be honest it is a very difficult process. […] This is something the company needs to really invest in."[12] Looking at the enormous potential for Desso from C2C, he concludes "So that way of thinking is an enormous driver for innovation and this innovation is then also obviously the driver for new technology."

In the case of **Herman Miller**, the collaboration with Braungart and McDonough already started in the late 1990s. The US-based manufacturer of office furniture, founded in 1953, looks back at a

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[9] Source: http://www.desso.com/c2c-corporate-responsibility/cradle-to-cradle/, access date 30.01.2014

[10] Source: http://www.desso.com/c2c-corporate-responsibility/declaration-suppliers/, access date 30.01.2014

[11] Source: Interview with Rudi Daelmans, Director of Sustainability Desso

[12] Source: Interview with Rudi Daelmans, Director of Sustainability Desso

company history coined by constant commitment to sustainability and environmental stewardship. Founder D. J. De Pree established for example green areas or natural airing systems in Herman Miller buildings and founded the Environmental Quality Action Team. De Pree is often cited with his vision of being "a good corporate neighbor by being a good steward of the environment" (Rossi et al. 2006; Braungart, McDonough 2011). Following the company values, the program "Perfect Vision" has been launched with concrete targets to be achieved by 2020 and C2C playing a major role for their pursuit, such as zero hazardous waste generation or 100% green electrical energy use.[13]

C2C efforts and main milestones

The foundation and core element of Herman Miller's C2C implementation is the tool "Design for Environment" to assess all product materials and process steps of production based on C2C criteria. This criteria has been co-developed by Herman Miller and the C2C consultancy formed by Braungart and McDonough (McDonough Braungart Design Chemistry, MBDC).[14] A formal process based on colored decision criteria, e.g. green for "little to no hazard", yellow stands for "low to moderate hazard", orange for "incomplete data" and red signifies "high hazard", materials are assessed and different indicators are calculated, either by the Herman Miller responsible (HM) or by the external firm MBDC. The ultimate target of the evaluation process, illustrated in figure 4, are products that are either 100% biological or technical nutrients that fit into the respective C2C metabolism (Rossi et al. 2006; McDonough et al. 2003).

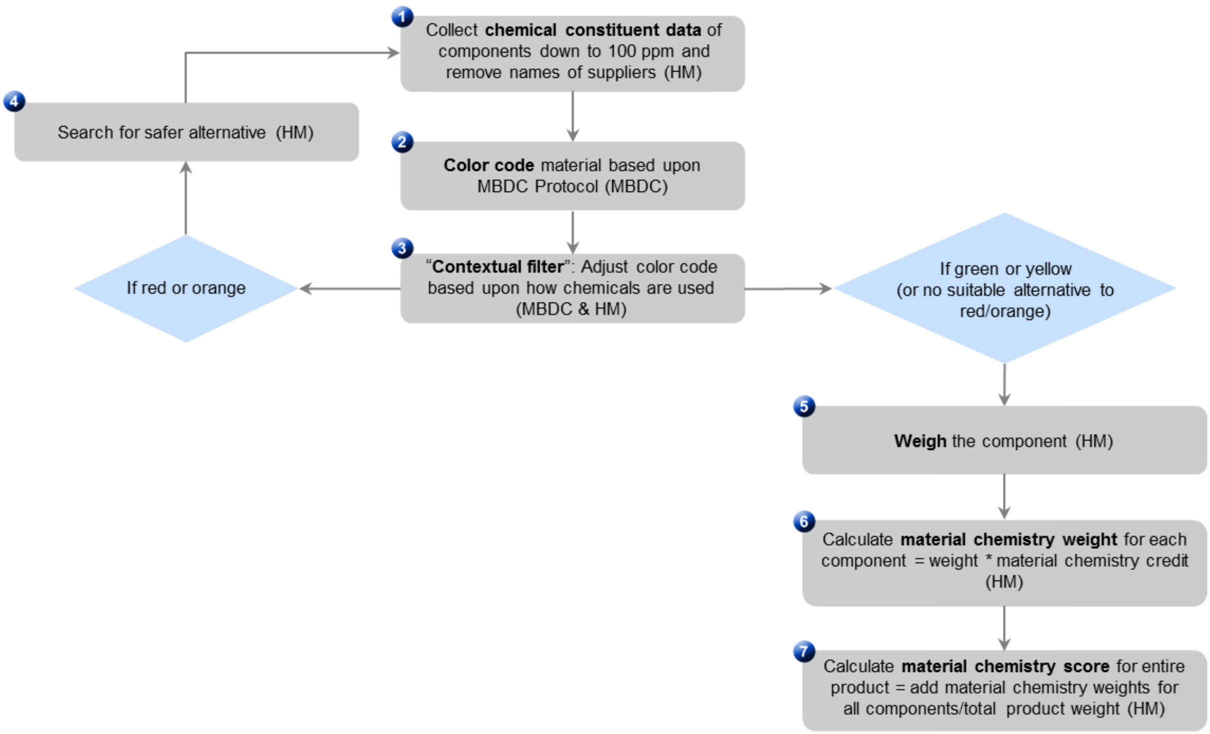

Figure 4: Herman Miller material chemistry evaluation process (illustration after Rossi et al. 2006)

The first success after the shift to C2C was the Mirra Chair, introduced in 2003, this office chair is an innovation in the category of office furniture as the chair can be fully disassembled

[13] Source: http://www.hermanmillerasia.com/About-Us/Environmental-Advocacy/Our-Vision-and-Policy, access date 31.01.2014

[14] See detailed homepage: http://www.mbdc.com/

and materials can be reused in a closed loop cycle. It is assembled using 100% renewable energy and has received extremely positive response by the markets along with several awards and prizes (Rossi et al. 2006). Today, Herman Miller has over 20 products C2C certified, including office chairs, tables or storage furniture. The commitment to a long-term strategy in line with C2C was emphasized by the appointment of a dedicated full-time team of experts who extensively worked on product designs and concepts according to the C2C criteria catalogue (Rossi et al. 2006). In our interview with Thaddeus Owen, Chief Engineer Sustainability at Herman Miller, Owen underlines the importance of the early C2C inclusion in the product development process "Cradle to Cradle thinking has been added to designers' toolbox".[15]

Benefits and challenges

Using such an elaborated tool as the DfE program is certainly helpful for Herman Miller and contributes to a long-term application of the C2C principles. Clear structures are established and Herman Miller becomes a learning organization with a learning curve that enhances C2C success for following products. Based on the achievements of the Mirra Chair, material types and possible substitutes, recycle characteristics and lists of compliant suppliers are all documented and positively leverage the C2C rollout across different product types (Rossi et al. 2006; Braungart, McDonough 2011). In particular it is the relationship to Herman Miller's supply base that changed after the C2C introduction. Owen summarizes the positive effects during our interview "we have a much more intimate handle on the material that we receive and what material chemistry they are made up from. So just because we have a higher level of oversight on our suppliers I think, they are motivated to supply more consistent and higher quality material to us".[16] The new requirements did not only affect product quality but also enforced a more solid relationship between Herman Miller and the supply base. Even though challenged with some skepticism from certain suppliers who are not willing to disclose material ingredient details, many convinced suppliers today collaborate and co-develop new ideas for substitution materials in order to fulfill C2C criteria (Rossi et al. 2006). However, the way to achieve this success has demanded resources and effort from Herman Miller who conducted face-to-face meetings with more than 200 members of the full supply chain. Declarations were accurately elaborated in order to conform to all partners involved. Other investments occurring in the short-run are related to the elimination of toxic material. The armrest of the Mirra Chair for example is normally made from PVC which is a red-tagged material in the C2C criteria due to its high hazardous effects. The shift from PVC to a different material (TPU - Thermoplastic polyurethane) which can be molded and re-used without loss of quality created additional cost. At the same time, other shifts to C2Ccompliant materials, e.g. coatings from nylon instead of steel, reduced the overall cost. To understand and balance such effects it is important to involve environment requirements into the very early design stages in order to minimize cost of internal change (Rossi et al. 2006). Owen clearly sees the positive impact of C2C on the innovation process: "That [C2C] has kind of accelerated innovation in our company and uniqueness of the way that we build high end computer task chairs". He sees an important opportunity for companies by applying C2C "in terms of innovation though, companies that are at an earlier place in their sustainability journey

[15] Source: Interview with Thaddeus Owen, Chief Engineer Sustainability Herman Miller

[16] Source: Interview with Thaddeus Owen, Chief Engineer Sustainability Herman Miller

can certainly benefit from innovation by utilizing some of these [C2C] strategies."[17]

4 Results

The theoretical review of the academic C2C scholarship revealed a very limited coverage in the high quality research landscape. Particularly, there is a lack of empirical work and linkage to related theories from the business context. The theory of the Fuzzy Front End in the innovation process proved to be a suitable theory to analyze C2C success factors and foster C2C implementation. Looking at the current state of practical C2C implementation, the results revealed a broad acceptance despite the newness of the concept. Almost 150 companies from numerous industries serving different target groups have already certified products at the C2C Products Innovation Institute. Moreover, we asserted that over 90% of the companies were large and established players in their markets. This might be owed to certification costs which younger firms are not willing or able to pay. However, even after considering a certain bias due to the cost of certification, the analyzed set underlines the high relevance of C2C for technology leading firms. Taking into consideration that many companies only possess one certificate whilst other count up to thirty or forty certificates, the case study research helped to derive potential enablers and driving forces for a holistic adoption of C2C.

The analyzed cases of the office furniture manufacturer Herman Miller and carpet manufacturer Desso aimed at a deeper understanding of success factors in C2C implementation. In both companies, the endorsement of the C2C idea through senior leadership ensured a consistent approach to C2C integration in all relevant FFE stages. This point became very explicit when our interview partners explained initial hurdles that had to be cleared. It was also very helpful that the top management team concretely anchored the C2C idea in the company's target and its vision. Looking at the technology and capabilities of the company, Desso has taken a large step to appropriate C2C-specific expertise. Not only by dealing with supplied materials but also by developing a new technology for the separation of carpet tile backs. This advancement has brought a new customer base through the establishment of a new business model to the firm as all carpet brands can be returned to Desso. It has also helped in getting specific funding and support. Overall, Desso has gained a new core competence and benefits substantially with regards to capabilities proprietary to the firm. Also in the case of Herman Miller, a company-specific tool enlarged the set of capabilities and introduced new technologies. The establishment of the Design for Environment (DfE) assessment tool is a critical element for Herman Miller in the long-term process of rolling C2C out throughout the full range of products.

Coming along with the capability building and development of new technologies, the engagement in new alliances is a key component in C2C implementation. Both companies clearly stated the significance and dependence on third party information, especially coming from suppliers. As accurate understanding and selection of product substances is necessary for C2C innovations, the first steps of analysis proved to be very challenging. The companies were confronted with confidentiality issues at the supplier side as well as with lack of expertise in certain areas, e.g. hazardous effects of certain materials, their recyclability, etc. In both companies, it was the early involvement of C2C criteria in cooperation with subject matter experts that enabled the teams to succeed the C2C products. Overall, both companies

[17] Source: Interview with Thaddeus Owen, Chief Engineer Sustainability Herman Miller

experienced clear advantages resulting from C2C implementation. Stronger relationships to suppliers and other value chain actors enable an improved material quality and product functionality. Both companies benefited from enhanced market reception. One drawback remains with regards to the measurement of C2C impacts on the corporate performance. Though Herman Miller established a quantitative assessment tool, it remains a challenge to quantify the economic effects of C2C implementation. Desso's performance has clearly improved with the introduction of C2C. However the direct effects could not be measured in both cases yet.

5 Discussion and implications

The paper aimed at identifying the success factors from FFE theory that can be transferred to the implementation process of C2C. Based on the presented analyses, many intersections appear. As presented in the FFE section, Senior Management Involvement, Technology and Capabilities as well as Alliances and Partnerships significantly contribute to a successful management of the early phases in the innovation process.

Senior Management Involvement: Understanding the importance of an early commitment and a constant support of top management during the early design phases was identified as a critical enabler for companies when starting C2C adoption. Not only the dedication of resources in monetary form or as specific C2C working groups affected the capability to overcome initial barriers. Moreover, the cases revealed that important decisions with regards to the product characteristics and its strategic fit to the company's vision had to be taken in the very early conception phase. In Desso's case, for example, the successful realization of a carpet that absorbs fine dust was only possible because the decision was taken during the opportunity identification phase. Hence, attention and influence-taking occurred when the product was designed and materials selected. The empirical evidence from FFE research with regards to top management endorsement is corroborated for the C2C concept. One additional insight is revealed when looking at the critical role that the CEO plays in both cases. It seems that not only senior leadership commitment is a success factor, but one critical driving force is also the CEO as C2C ambassador.

Technology and Capabilities: In both cases specific capabilities and enabling technology played an important role throughout the C2C implementation process. Through their DfE assessment tool Herman Miller evaluate all substances that go into the product and the associated production processes. The program has a big effect on all C2C-related decisions and ensures the retaining of specific knowledge. Overall, we saw that the needed expertise poses challenges, especially with regards to the realization of the company's first C2C product. It is not necessarily possible to gather needed information about substance characteristics or potential substitutes established teams or structures of the company. This underlines the importance of an accurate documentation process so that the new capabilities can be established once the needed data has been acquired and design issues resolved. This success factor might also explain the high percentage of technology leading firms in the set of C2C certified companies. Advanced expertise seems to play an important role when facing the C2C challenge. The comparison to a startup firm having implemented C2C would reveal valuable insights on this question.

Alliances and Partnerships: The relevance of stakeholder involvement was striking in both cases. Without a solid and trustful relationship to their suppliers, Herman Miller and Desso would not have been able to implement C2C successfully. Other actors like independent institutions are needed in order to verify material characteristics, consult the company about potential hazardous effects or suggest opportunities for replacements. Thus, it can be assumed that C2C implementation becomes easier and eventually more successful in industries where numerous players adhere to the C2C concept benefiting from the learning effect of all stakeholders involved. The key role of suppliers demands special attention as their role seems to exceed what empirical evidence from FFE theory has shown so far. A strategic and holistic approach to manage third party actors during the innovation process could have a very positive effect on C2C activities and contribute to a reduced need for resources.

6 Limitations and further research

The presented work bases on preliminary case studies which will be enriched with more interviews in the course of the research effort. The descriptive analyses on the set of C2C certified products give a first impression on related issues and questions to ask. The following activity comprises of a quantitative examination on C2C enablers. Despite the limited empirical coverage of the C2C topic, especially in relation to innovation management, this first analysis revealed valuable insights on C2C success factors derived from empirical evidence on Fuzzy Front End. Due to the high importance of early C2C integration into the innovation process, it becomes a key component of the front end activities of a company. As these stages often lack a strategic approach, the conjoint analysis of these concepts becomes crucial for company aiming at C2C implementation. While it became clear that C2C spurs innovation in the presented cases, a deeper understanding of the driving forces and enablers would add much value to the discussion of C2C implementation. In particular, the broad rollout of C2C within a company would be of high relevance when analyzing success factors. Building on the results of the investigated cases, it can be assumed that theory is lagging behind practice with regards to strategic C2C implementation into the innovation process. As we saw in both companies, a tailored and company-specific approach has been established. In theory however, there is no such link yet. Moreover the role of the customers during the C2Cspecific idea generation and conception still vague and needs closer attention through further analyses. Building on the foundations of this paper, a quantitative analysis of a larger set of companies will contribute to the identification of enablers to C2C implementation in the innovation process and foster the generalization potential of the results.

7 References

Bjørn, A.; Hauschild, M. Z. (2013): Absolute versus Relative Environmental Sustainability. What can the Cradle-to-Cradle and Eco-efficiency Concepts Learn from Each Other? In *Journal of Industrial Ecology* 17 (2), pp. 321–332.

Braungart, M.; McDonough, W.; Bollinger, A. (2006): Cradle-to-cradle design: creating healthy emissions – a strategy for eco-effective product and system design. In *Journal of Cleaner Production* 15 (13-14), pp. 1–12.

Braungart, M.; McDonough, W. (Eds.) (2011): Die nächste industrielle Revolution. Die Cradle to Cradle - Community. EVA Europäische Verlagsanstalt GmbH u. Co. KG. 3rd ed., Leipzig: CEP Europäische Verlagsanstalt.

Byggeth, S.; Hochschorner, E. (2006): Handling trade-offs in Ecodesign tools for sustainable product development and procurement. In *Journal of Cleaner Production* 14 (15-16), pp. 1420–1430.

Carrillo-Hermosilla, J.; del Río, P.; Könnölä, T. (2010): Diversity of eco-innovations: Reflections from selected case studies. In *Journal of Cleaner Production* 18 (10-11), pp. 1073–1083.

Cooper, R. G. (1988): Predevelopment activities determine new product success. In Industrial Marketing Management 17 (3), pp. 237–247.

Cooper, R. G.; Kleinschmidt, E. J. (1987): New products: What separates winners from losers? In *Journal of Product Innovation Management* 4 (3), pp. 169–184.

Cooper, R. G.; Kleinschmidt, E. J. (1991): New product processes at leading industrial firms. In *Industrial Marketing Management* 20 (2), pp. 137–147.

Crainer, S. (2012): A good yarn. In *Business Strategy Review* (1), pp. 44–47.

Eisenhardt, K. M. (1989): Building Theories from Case Study Research. In *Academy of Management* 14 (4), pp. 532–550.

Ellen McArthur Foundation (2012): Towards a Circular Economy: Economic and business rationale for an accelerated transition.

Gou, Z.; Lau, S. S.-Y. (2012): Sick building syndrome in open-plan offices: Workplace design elements and perceived indoor environmental quality. In *Journal of Facilities Management* 10 (4), pp. 256–265.

Hanssen, O. J. (1999): Sustainable product systems—experiences based on case projects in sustainable product development. In *Journal of Cleaner Production* 7 (1), pp. 27–41.

Herstatt, C; Verworn, B. (2007). Management der frühen Innovationsphasen, 2nd ed., Wiesbaden: Gabler.

Huesemann, M. H. (2004): The failure of eco-efficiency to guarantee sustainability: Future challenges for industrial ecology. In *Environmental Progress* 23 (4), pp. 264–270.

Khurana, A.; Rosenthal, S. R. (1998): Towards Holistic "Front Ends" In New Product Development. In *Journal of Product Innovation Management* 15, pp. 57–74.

Koen, P. A.; Ajamian, G.; Boyce, S.; Clamen, A.; Fisher, E. et al. (Eds.) (2002): Fuzzy Front End: Effective Methods, Tools, and Techniques. In Belliveau, P.; Griffin, A.; Somermeyer, S. (eds): The PDMA ToolBook for New Product Development. New York: John Wiley & Sons, pp. 5–35

Koen, P. A.; Ajamian, G.; Burkart, R.; Clamen, A.; Davidson, J. et al. (2001): Providing Clarity and a Common Language to the "Fuzzy Front End". In *Research-Technology Management* 44 (2), pp. 46–55.

McDonough, W.; Braungart, M. (2002): Design for the Triple Top Line: New Tools for Sustainable Commerce. In *Corporate Environmental Strategy* 9 (3), pp. 251–258.

McDonough, W.; Braungart, M. (2013): The Upcycle. Beyond Sustainability - Designing for Abundance. New York: Melcher Media.

McDonough, W.; Braungart, M.; Anastas, P. T.; Zimmerman, J. B. (2003): Applying the Principles of Green Engineering to Cradle-to-Cradle Design. In *Environmental Science & Technology* 37, pp. 434–441

Pluijm, F.; Miller, K. M.; Cuginotti, A. (2010): Backcasting Using Principles for Implementing

Cradle-to-Cradle. In Sarkis, J.; Cordeiro, J. J.; Vazquez Brus, D. (eds.): Facilitating Sustainable Innovation through Collaboration. Dordrecht: Springer, pp. 203–216.

Reay, S. D.; McCool, J. R.; Withell, A. (2011): Exploring the Feasibility of Cradle to Cradle (Product) Design: Perspectives from New Zealand Scientists. In *Journal of Sustainable Development* 4 (1), pp. 36-44.

Rossi, M.; Charon, M.; Wing, G.; Ewell, J. (2006): Design for the Next Generation: Incorporating Cradle to Cradle Design into Herman Miller Products. In *Journal of Industrial Ecology* 10 (4), pp. 193–210.

Schmidt, W. P.; Dahlqvist, E.; Finkbeiner, M. et al. (2004). Life cycle assessment of lightweight and end-of-life scenarios for generic compact class passenger vehicles. In *International Journal of Life Cycle Assessment* 9(6), pp. 405–416.

Senge, P. (Ed.) (2008): The necessary revolution. Working together to create a sustainable world. New York: Broadway Books.

Song, Y. S.; Youn, J. R.; Gutowski, T. G. (2009). Life cycle energy analysis of fiber reinforced composites. In *Composites Part A* 40(8), pp. 1257–1265.

Specht, G.; Beckmann, C. (1996): F&E-Management. Stuttgart: Schäffer-Poeschel.

Tietze, F.; Schiederig, T.; Herstatt, C. (2013): Firms' transition to green product service system innovators: cases from the mobility sector. In *International Journal of Technology Management* 63 (1/2), pp. 51–69.

Von Hippel, E. (1988): The Sources of Innovation. Oxford: Oxford Univ. Press.

Webster, J.; Watson, R. T. (2011): Analyzing the Past to Prepare for the Future: Writing a Literature Review. In *MIS Quarterly* 26 (2), pp. xiii–xxiii.

Wheelwright, S. C.; Clark, K. B. (1995): Leading Product Development. The Senior Manager's Guide to Creating and Shaping the Enterprise. New York: The Free Press.

World Business Council for Sustainable Development (2000): Eco-efficiency. Creating more value with less impact.

Yin, R. K. (2009): Case Study Research: Design and Methods. 4th ed., Thousand Oaks: Sage Publications Inc.

Zhang, Q.; Doll, W. J. (2001): The fuzzy front end and success of new product development a causal model. In *European Journal of Innovation Management* 4 (2), pp. 95–112.