Faculdade de Design,
Tecnologia e Comunicação
Universidade Europeia

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ANA CATARINA ANGÉLICO DA COSTA ESPADA

DESIGN AS A SOURCE OF INNOVATION TO ESTABLISH CIRCULAR BUSINESS MODELS: HOW TO PREVENT THE SINGLE-USE OF PLASTIC?

Tese apresentada ao IADE - Faculdade de Design, Tecnologia e Comunicação da Universidade Europeia, para cumprimento dos requisitos necessários à obtenção do grau de Doutor em design realizada sob a orientação científica da Doutora Isabel Maria Bernardo Pereira Farinha, professora auxiliar do IADE – Universidade Europeia e do Doutor Carlos Alberto Miranda Duarte, professor catedrático do IADE – Universidade Europeia.

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“Não ficarei sentado a ver a vida
os meus cavalos correm noutros campos”
(Manuel Alegre)

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Palavras-chave Design; Inovação; Economia Circular; Embalagem plástica; Reutilização.

Resumo

A relação entre o design e o aumento da competitividade económica pela criação de valor já tem sido abordada. Não obstante, no contexto atual em que a economia transita de modelos lineares para circulares está a estabelecer um paralelismo extraordinário entre os modelos económicos e os princípios de design. Novas soluções de design podem apoiar a transição de produtos, processos e modelos de negócios para um modelo que potencie a criação de benefícios monetários e ambientais, aumente a eficiência dos recursos pela minimização de desperdícios e recuperação de resíduos e, estimule de uma forma sustentável a cadeia de valor de produtos e serviços, matérias-primas e materiais.

A reciclagem tem sido apontada como a principal estratégia para a economia circular do plástico, mas não deixa de ser um paradoxo, uma vez que a procura do setor é significativamente inferior à quantidade reciclada de acordo com a literatura analisada.

O objetivo geral deste estudo, é explorar o modo como os princípios de design aplicados aos conceitos de economia circular fomentam a inovação e a transição de um modelo linear de gestão para um modelo económico regenerativo e restaurador. Donde, a seguinte pergunta de investigação: "Como pode o design ser uma fonte de inovação para transformar modelos de negócios de acordo com princípios da economia circular?". O objetivo específico desta investigação é desenvolver o nosso modelo resultante do *reverse design* e que se pauta pela definição de uma estratégia de modelo circular (System-Centered Circular-Design, SCCD) e, em paralelo, aferir o conhecimento relacionado com as suas diferentes variáveis.

Metodologicamente optou-se por uma abordagem qualitativa, para analisar o impacto dos conceitos de design de embalagens ao longo da definição dos modelos de negócio e dos seus ciclos.

Neste âmbito, começou primeiramente, por se selecionar como caso de estudo, a solução de design WisePack para analisar o ciclo de desaceleração e fecho (*slowing and closing loops*). Esta solução de design para as embalagens plásticas, maximiza a funcionalidade do produto e do material, resultante do processo de design e manufatura.

Apresentam-se os pressupostos dos modelos de negócios circulares WisePack, seguidos das entrevistas realizados às partes interessadas que orientam a análise do estudo de caso.

O estudo de caso da WisePack descreve as questões mais importantes a ponderar na seleção dessas estratégias de design e define os modelos de negócios circulares num estágio inicial de design de produto e serviço.

A natureza qualitativa da investigação visa obter informações de diferentes ângulos para compreender as restrições e os objetivos dos principais agentes envolvidos na cadeia de valor. Com base nos resultados das entrevistas semiestruturadas destacam-se quatro fatores com potencial de fomentar a transição de uma abordagem linear para uma circular, a saber: i) o design tem uma relação relevante com os seus modelos de negócio; ii) barreiras à implementação do design, podem impactar a geração de valor; iii) o design pode influenciar e alterar a apetência para a inovar; iv) a captura de valor do negócio está relacionada com a cultura de inovação nos modelos lineares de negócios em prática.

De todo o modo, há a reter desta fase exploratória da investigação que a solução de design de embalagem apresentada durante as entrevistas - WisePack - pode ter alterado algumas das premissas feitas pelos representantes das diferentes partes interessadas da cadeia de valor.

Posto isto, e com base na revisão da literatura e na experiência profissional, constatou-se que a investigação etnográfica revela ser adequada para fornecer aos designers de sistemas circulares e aos decisores das empresas, perceções valiosas.

Em segundo lugar, e sob o intuito de testar o modelo System-Centered Circular-Design (SCCD) procurou-se compreender se o design pode condicionar os modelos de negócio das partes interessadas de toda a cadeia de valor. Daí, ser proposto um método com o objetivo de permitir que designers e gestores definam possíveis modelos de negócios circulares ajustados por princípios de design mais circulares - o SCCD.

Expõe-se a ferramenta SCCD e da sua sistematização decorrem vários conceitos para a construção de novas e mais complexas colaborações na cadeia de valor. Essa relação no processo circular é definida em termos de atributos. Os atributos, características geométricas e funções são utilizados para facilitar a instrumentação deste processo inovador. Todas essas caracterizações de notação de SCCD parecem ser viáveis para a especificação do processo e fase de projeto. Este, suporta

refinamento e abstração, tornando a estrutura SCCD fácil de entender e usar.

As tabelas de diagnóstico do modelo, visam apoiar os designers na identificação dos requisitos, restrições e oportunidades da abordagem circular. No entanto, também orienta a comunicação entre o designer e os representantes de cada departamento envolvido no processo de transição do modelo de negócio linear para o circular.

Com o objetivo de testar o modelo SCCD, cenários futuros foram desenvolvidos nesta investigação para poder ser estabelecida uma área de exploração e discussão sobre a adaptação do processo de design ao paradigma da economia circular. O foco tem por intuito facilitar a geração de ideias compartilhadas sobre a direção a tomar e as escolhas a fazer e promover soluções de design para a economia circular. Nesse sentido, é de extrema importância apresentar as tendências de contexto relevantes. Para o caso de prevenção do plástico de uso único, os cenários deverão levar em consideração as tendências futuras no comportamento dos utilizadores em relação ao reparo ou reutilização e devolução de produtos. Esses cenários também distinguem entre dois níveis diferentes de envolvimento desses utilizadores. Como é expectável, algumas partes interessadas terão que atender a necessidades diferentes de outras em menos tempo, ou com diferentes níveis de risco e investimento.

A finalizar, admite-se que novos testes piloto e trabalho de campo são recomendados para poderem ser validados os cenários futuros. Com efeito, e no decurso desta investigação, a complexidade da parceria e o investimento financeiro necessário, não possibilitaram a implementação do modelo. Daí que, se tenham construído duas narrativas a ilustrar os cenários futuros de prevenção à utilização do plástico de uso único, por meio do design.

Por fim, e com base nos resultados, constata-se que o modelo de definição de estratégia de modelo circular (SCCD) constitui uma ferramenta válida na senda dos objetivos desta investigação. Pode assim concluir-se que, os princípios do design quando aplicados aos conceitos da economia circular, conseguem tornar-se fonte de inovação e, que o modelo SCCD consegue suportar a transição dos modelos de negócios.

Keywords Design; Innovation; Circular-Economy; Plastic-Packaging; Reuse.

Abstract

The current economy context moving from linear to circular models is establishing extraordinary parallelism between with design principles. Design solutions can support the transition of business to one which creates monetary and environmental benefits, increases resource efficiency, and maintains the value of products, materials, and waste.

Recycling has been signaled as the main strategy for the plastics circular economy, but it presents itself as controversial since the industry's demand is significantly lower than the recycled amount.

The overall objective of this study is to explore when design principles, related to circular-economy concepts, become a source of innovation, in order to answer to the research question: "How can design be a source of innovation to transform businesses models accordingly to circular economy principles?".

The primary objective of this investigation is to develop our model resulting from reverse design and which is guided by the definition of a circular model strategy (System-Centered Circular-Design, SCCD) and the secondary objectives involve expanding the knowledge related to the various aspects of this model.

A qualitative approach was chosen, to analyse the impact of the packaging design concepts along the definition of the business models and its circular loops.

From the literature review ethnographic research is thus well suited to providing circular systems designers and companies decision-makers, with rich insights. WisePack design solution was selected to analyse the slowing and closing loop.

The relevant insights to retain from the exploratory phase is that WisePack may have changed some of the assumptions made by the different stakeholders of the value chain.

A SCCD toolbox is presented, to support designers identifying the requirements, constraints and opportunities of the circular approach.

To prevent the single-use of plastic, scenarios were developed, taking into consideration users' behaviour towards repair or reuse, taking-back products and their levels of engagement.

Based on the results, it was concluded that the circular model strategy definition model (SCCD) is a valid tool. Confirming the primary and secondary objectives of this study. Showing that design principles,

related to circular-economy concepts, become a source of innovation, and the SCCD model and toolbox, support the businesses models transformation.

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Doutor Tawfiq Rkibi, Reitor Interino e Presidente do Conselho Científico da Universidade Europeia.

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Doutora Isabel Maria Bernardo Pereira Farinha, Professora Auxiliar do IADE – Universidade Europeia;

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Doutora Aldina Maria Pedro Soares, Professora Adjunta da Escola Superior de Tecnologia de Setúbal do Instituto Politécnico de Setúbal.

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SCCD – System-Centred Circular Design

Key Terms and Definitions

Collapsible: Faculty of reducing volume, be foldable or create a state of (close to) vacuum, hermetically closure of a package, insulating its interior or protect it from outside influences and contaminations.

Refill: This phase refers to, when the packaging is collected, not to be delivered to the company that allows the recovery of materials, such as the reintegration of the material in the manufacture of similar products - plastics processing companies. But to be delivered to, for example, a detergent manufacturer, in order to fill the packaging several times and thus extend its use and additional sale of the same product.

Waste-Free Design: From the earliest stages of the design process, designers are thinking about solutions and material selection that, rather than being intended for disposal, should maintain their utility and value and flow back into the cycle.

INTRODUCTION

Research context

Today's world lives inspired by words which inclusively lead to important research lines - words like eco-design, innovation, sustainability and participatory design. The fact is that the concepts underlined in these words, and that are shaping tomorrow's trends, are suffering mutations forced by an incredible rhythm of change.

It is important to reflect on what the design process should provide to contribute effectively to innovating processes, business models and ultimately modify the design approach accordingly.

This global context motivated the present research work. Having as starting point the cradle-to-cradle broadest approach of John T. Lyle's regenerative design (Lyle, 1994) and its application on an economic, industrial and social levels to create efficient systems (linear economy) but also waste free and resources optimization (circular economy) (Ellen-MacArthur-Foundation, 2015).

The transition from a linear economy to a circular economy is a progress that will have to be reinforced by new policy, new business models, transformations in human behaviour, and by the development and implementation of strategies for the circular design of products and services in order to build a circular society.

Circular economy has a strong relation with product design, in a broader way. The replacement of the 'end-of-life' concept aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models (Ellen-MacArthur-Foundation, 2015).

Design is a relevant part of several processes aimed to narrowing, slowing down and closing loops accordingly to circular economy principles (Clift, 2015). The user is accepting that their participation on the process, is conscient of the impacts of the societal activities on the planet's resources and is demanding a change in the global economy.

The choice of plastic packaging to reverse the conventional design process, and develop a model that support designers and decision makers to stablish; analyse; and solve; design problems, is based on two main reasons:

. the heavy demands of European Commission on the prevention of single-use of plastic (European Commission, 2018b) (European Commission, 2018b);

. the miss perception of plastic as a highly circular resource, able to prevent serious environmental impacts.

Design for plastic circularity

It is essential to acknowledge that design should provide something additional to the sociological aspect of sustainability, since intrinsically they share considerations and societal principles, such as a user centred process in a moment that users and communities are actively participating in environmental crisis resolutions.

Innovative design has promoted economic valorisation of new ideas adopted by major companies and industrial groups. Nowadays, however, humans, technology and business suggest that new sources of innovation are emerging, in particular those that are centred around user concerns and aspirations. In this sense, design principles are positioning designers as major actors in the contemporaneous context of innovation. The designers' attention should thus not be oriented strictly to material artefacts (e.g. eco-design) or functionalities. The designers should instead participate in the development of new guidelines from a given set of existing specifications, arising from the new conceptualization of modern society, based on user demands, environmental obligations and business transition for circular models.

In summary, the design should concentrate on synthesizing all involved intervening expertise to deliver solutions that fulfil social and business expectations. Therefore, it is fundamental to analyse the value that design solutions can create through the life cycle of each design solution, the adjacent services to each product, and the key partners and stakeholders of the value chain.

In the multidisciplinary nature of the design systemic approach, not only perceptive attributes are considered, such as form, colour, texture, on an aesthetic and semiotic level, but also state-of-the-art technology and socio-environmental elements and business model transformations are constraints to the design process. Consequently, design may be a source of innovation to establish circular business models.

Research Problem and motivation

The uncertainty level and its effects on the design process depends strongly on the activity sector where business occurs. Today’s world lives beyond large changes compelled

by socio-environmental drivers and it influences all activity sectors, especially people's everyday lives. The plastics industry is one of the activity sectors that has been suffering significant pressure and business oscillations due to the environmental paradigm.

This study will focus on design as a source of innovation to establish circular business models and will make a specific analysis of how can design help to prevent the single-use of plastic packaging.

The demand for plastic packaging has increased over the years and this has led to its significant impact on various sectors of the economy. The plastic-packaging industry model of consumption is linear and dates back to the Industrial Revolution, and nowadays the global economy develops around the consumption model of *take-make-use-dispose*. However, various social, economic and environmental factors mean that it is no longer sustainable.

It is essential to grasp the roots of the process of design for sustainability to understand the implications that may occur in the present transition from a linear to a circular economy approach (De los Rios & Charnley, 2017). It is also important to understand what centralised versus decentralised production currently means and how it sustains or constrains the design approach to circular business models at several levels: product development, system and ecosystem levels (value chain).

Recognising the earth as a limited source of energy and resources, consider waste a potential and not a defeat, are in the basis of a circular economy as a philosophy. Business in general, as well as product design in particular, are experiencing an increasing pressure to move from a linear to a circular approach in order to help reduce our global sustainability strain (Bocken et al., 2016). In the centre, aiming to become effective actors in the necessary transition from an industry relying on fossil fuels, are designers, innovators, and decision-makers in all businesses. Their selling drivers are now centred on the use of renewable energy, designing services that profit from several time resources flows and the design to reuse products, materials continuously (Bakker, 2019).

An historical review of the concept of the circular economy is presented, aiming to give insights into business models and the current product design and capable of promoting the transition from a linear to a circular economy approach.

Moving from linear economy to a circular economy have felt the combined effects of changes in design where, rather than being destined for disposal, materials should

maintain their utility and value and flow back into the cycle. The transition to business, which creates monetary and environmental benefits, has paved the way for the development of new business models focused on increasing resource efficiency, ensuring the value of products, materials and waste valorisation. Although the relationship between design and actual success of business has been often addressed, the overall objective of this research is to explore design strategies related with circular-economy, where product-design is a source of innovation for business models, impacting the plastic-packaging value chain on a system level.

Objectives of the study

Overall objective

The overall objective of this study is to explore when design principles, related to circular-economy concepts, become a source of innovation, in order to answer to the research question: "How can design be a source of innovation to transform businesses models accordingly to circular economy principles?".

Primary objective

The primary objective of this investigation is to develop our model resulting from reverse design and which is guided by the definition of a circular model strategy (System-Centered Circular-Design, SCCD)

Secondary objectives

The secondary objectives involve expanding the knowledge related to the various aspects of the developed model (e.g. circular design archetypes; tool specifications for circular design processes).

Research question

This controversy guided the study to the research question:

"How can design be a source of innovation to transform businesses models accordingly to circular economy principles?"

In order to answer to this research question and make sure the goals of the research are answered two secondary questions were stablished:

. What are the archetypes on a circular product value chain?

. Is possible to create a framework and tool to support creation, analysis and execution of specifications and formal processes of circular design?

Research design

This study focuses on the change of ownership-obligations of the plastics manufacturers and their responsibility to ensure the reliability and duration of the products. Product-service system approaches will be addressed in various scenarios, aiming to urge manufacturers to provide reuse and take-back systems, at a liable cost on refill, labour and aftermarket.

The application of this research problem is applied (third vertical Figure 1) to a case study of WisePack, a collapsible packaging solution. This is an interesting object to shape this research challenge, since it addresses the issue of the financial and environmental costs in transportation, storage and after use collection of blow-moulding plastic bottles, produced in a centralised business model. The case study of a packaging solution is at the basis of:

- the business model analysis, aiming to reverse the design process and to establish on the one hand the design guidelines for circularity, and on the other hand waste-free concepts generation (Economic).

The outcome of the case study reverse process can draft the:

- design guidelines for circularity and waste-free solutions (Environmental);
- from general design parameters, innovation in products emerge, taking into consideration human aspirations and concerns – answering to a more participative, more environmentally-conscious and more demanding end-user (Social).

The outcome of the case study reverse process drafts the design guidelines for circularity and waste-free solutions. Integrating circular economy principles at an early stage of the design process is important because once product specifications are determined, only minor changes are usually possible. Finally, from general design parameters, innovation in products emerge, taking into consideration human aspirations and concerns – answering to a more participative, more environmentally-conscious and more demanding end-user.

The Research proposition is summarized in below (Figure 1), where in the vertical axes, the proposition steps can be seen: the research problem and the scientific fields that

give the study the theoretical background – Design, Circular Economy and the Plastics industry. The main authors supporting this research proposition will be listed on the next section, organized by chapters (Figure 2) and the main authors supporting the methodology and analysis are in the methodology section (Figure 7).

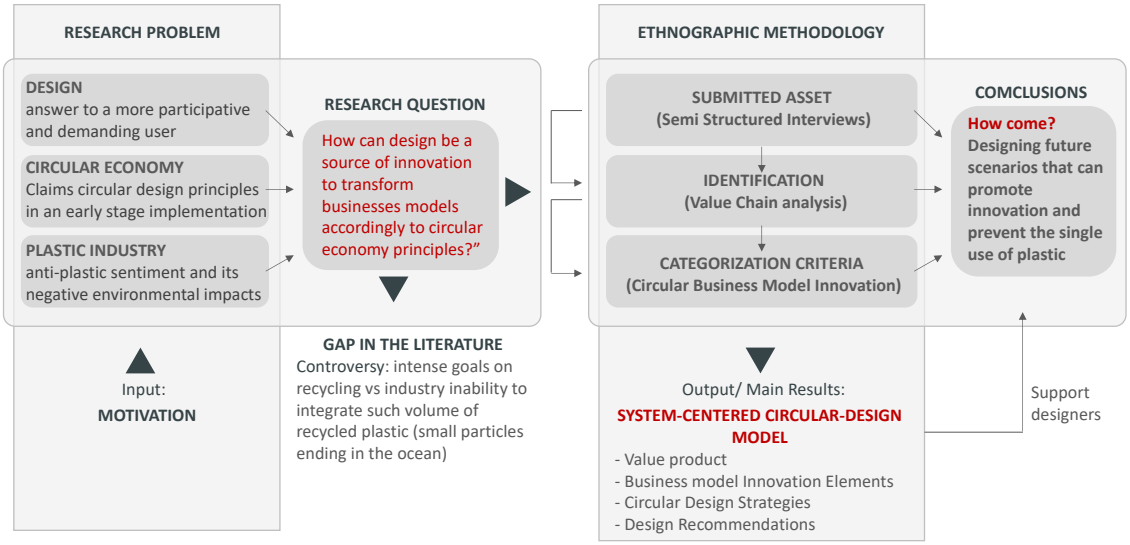


Figure 1. Research proposition

In the second vertical level, the gap in the literature is identified as a controversy. Despite the fact that the most common circular strategy embraced by the plastics industry is recycling, this industry is not capable of integrating these large amounts of recycled plastic which will most likely end up in landfills or in the ocean.

Thesis organisation

Based on the assumptions described in the previous section, that reversing the design process will generate guidelines that will draft future recommendations for circular and waste-free design, the thesis is organised in six distinct chapters. The organization of the thesis is illustrated in the Figure 2.

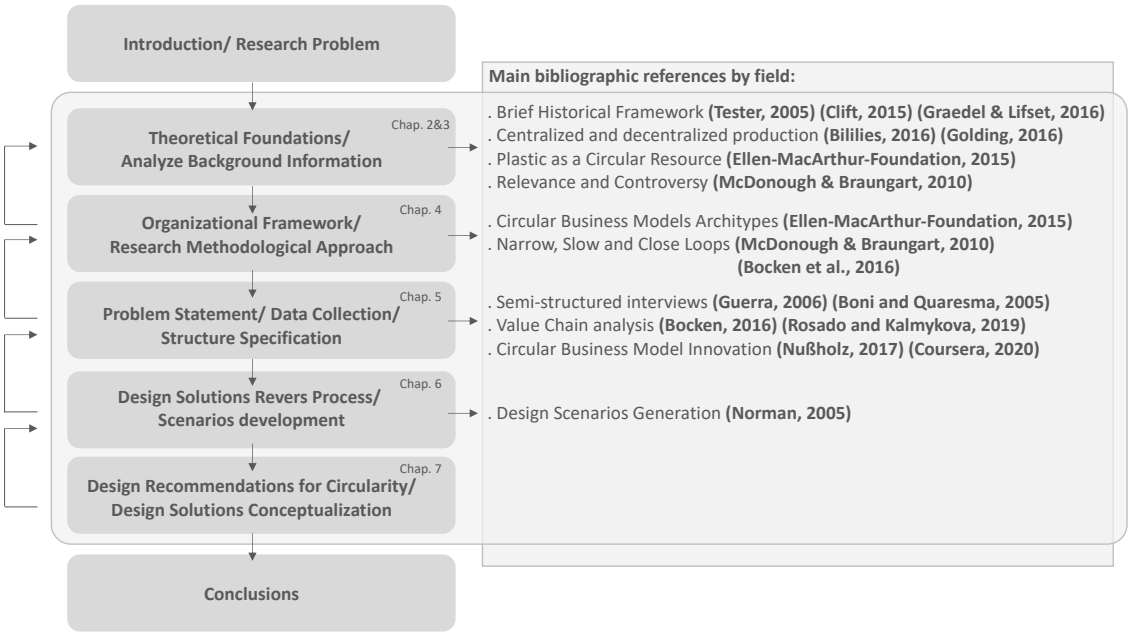


Figure 2. Thesis organisation

An introductory chapter. Chapter one provides a brief historical analysis that relates to industrial ecology and design principles. Stresses the importance of drafting future recommendations to circular approach designer, on a system level. And discussed circular strategies to extend products lifetime through "Narrow", "Slow" and "Close" product resource flows.

Chapter two, is an introduction to circular design. Topics include eco-design, methods to assess environmental impacts, and collaboration networks. Basic concepts are introduced, such as centralised and decentralised production in the plastic packaging industry and plastic as a circular resource.

Chapter three describes the conceptual framework of design as a principle of understanding the activities that are to be performed in the application of the methodological tools. The structure of the research and the methodologies used is presented. Four factors were defined as relevant to promote the transition from a linear to a circular approach

Chapter four focuses on the problem statement, introduces the case study and innovation approaches are discussed. The chapter starts to describe the principle of WisePack. In this section the WisePack circular business models' assumptions are described, followed by the stakeholder's interviews and finally, guide the case study analysis developed in the next chapter.

Chapter five is dedicated to the design guidelines. Recommendations for circularity are generated with the methodological tools as well as the product and value chain analysis, and value creation scenarios are generated. The Wisepack case-study outlines the most important issues that need to be considered in selecting these design strategies and define the circular business models in an early stage of product and service design.

Chapter six explores design concepts to validate the design recommendations and guidelines found, while in last section presents the main conclusions of the thesis are drawn, and further work identified. A SCCD toolbox is presented. Those canvas aim to support designers in identifying the requirements, constraints and opportunities of the circular approach.

1. THEORETICAL FOUNDATION – DESIGN FOR CIRCULAR ECONOMY

It is clear that sustainable development cannot be regarded merely as an environmental statement to the extent that economic and social issues are closely related. A change of mentalities is needed, basically in what concerns the consumption patterns that are implied in what is still today understood as quality of life, if sustainability is to be attained (Tester, 2005).

Sustainability is necessarily subjective because it reflects human value – the relative importance stakeholders assign to the activity to be sustained, to the perceived benefits of that activity, and to other values "traded-off" to sustain the activity in question (Tester, 2005). Additionally, due to the fact that sustainability is a long-term issue and the effects of non-sustainable behaviour are often delayed in time, companies tend to focus their effort on short-term issues and avoid problems that are not imminent. However, many companies are becoming increasingly conscious of the need to change their practices.

In fact, the environmental strategies of companies have been evolving over time. The first strategies to be introduced were of a compliant nature, i.e., strictly related to environmental regulation and pollution control, and were therefore process-oriented. In order to assess compliance, these strategies make use of tools such as energy and environmental audits. Improved strategies arise with extended environmental consciousness and product responsibility, introducing life-cycle thinking.

The focus of these strategies is on products/services and on the minimization of the environmental impact throughout their life-cycle, i.e., from the extraction of material to final product disposal, passing the use stage. Life Cycle Assessment (LCA) is an assessment tool of the environmental performance of the product or service that accounts for all the relevant flows of energy and materials (Ferrão, P., 1998).

Design for sustainability emerges in this strategic context as a life-cycle thinking design approach in which the design goals are those of minimizing the consumption of resources, minimizing emissions and facilitating the disposal of the product at its end-of-life, ideally with good prospects for reuse and recycling. Life cycle assessment is the preferential tool for assisting the design for the sustainability process. Finally, it is necessary to mention that the most recent and holistic environmental strategies are those based on industrial ecology. These strategies are aimed at closing loops in industrial ecosystems,

namely by promoting the exchange of waste across industrial sectors and energy cascading utilization and are therefore system-oriented.

1.1 Evolution of the concept of industrial ecology and design

The origins of industrial ecology date back to 1972. On the United Nations Conference on the Human Environment in Stockholm, a global environmental movement was initiated (Handl, 1972). Almost 30 years after the Stockholm declaration, General Motors published the document Strategies for Manufacturing, which discussed the environmental impacts of manufacturing, speculating on resource reduction and waste accumulation (Clift, 2015).

The authors refer to the need for transformation of the traditional model of industrial activity, into a more integrated model: an industrial ecosystem (Clift, 2015). Due to being a system, the consumption of energy and materials becomes intense, if optimised, the generation of waste is minimized, and the effluents from one process could serve as raw material for another (Bumble, 2019) . However, these reflections refer to the industrial model in 1972, while today's industrial models are still linear.

Other ecosystem analyses have been discussed over the years and it was in a publication in 1994, in the fields of industrial ecology, where the idea of industrial metabolism was first presented. The goal of industrial ecology was to archive a state close to optimal, where nature prevails the most (Andrews, 2015). The industrial metabolism integrated all the industrial processes that transform raw materials and energy, plus the labour inherent in those transformations, into products and industrial waste, comprising a systematic approach that *completes or nearly-completes internal cycling of materials* (Bocken et al., 2016).

In 2009, the book *Materials and the Environment: Eco-Informed Materials Choice*, written by Michael Ashby, professor of engineering at the University of Cambridge, enabled a wide acceptance of design's contribution to the environment (Ashby, 2012).

In 2010, Jackson (Clift, 2015) definition of sustainability is one of the most succinct: *Sustainability is the art of living well, within the ecological limits of a finite planet,* and this awareness of the limits of a finite planet has never been acknowledged as it is now.

Presented below is a brief historical review of main industrial ecology concepts, based on the article *Industrial Ecology's First Decade* (Graedel & Lifset, 2016) and based on previous work of this research (Espada, 2020):

- **Life-cycle assessment (LCA):** is the methodology that seeks to identify the environmental impacts of a product or process at each stage of its life cycle;
- **Design for environment:** consider environmental factors such as minimizing energy requirements, decreasing discards from manufacturing, choosing more sustainable materials;
- **Material flow analysis (MFA):** is the methodology for quantifying the stocks, flows, inputs, and losses of a resource;
- **Socio-economic metabolism**: the ultimate task of this area of study is to relate resource transitions to societal change and to prospects for and measurement of sustainability;
- **Urban Metabolism:** quantified flows of human and animal food, glass, plastics, sewage, sulphur dioxide emissions and the analysis of the intensification of the food, water and material consumption per capita;
- **Industrial Symbiosis:** the organisation of industrial organisms and their processes so that the waste of one process is the raw material or the input for another, usually in a specific regional or national setting;
- **Circular Economy:** is an industrial system that is restorative or regenerative by intention and design. It replaces the 'end-of-life' concept with restoration, transition towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models (Ellen-MacArthur-Foundation, 2015) (diagram annex 1).

1.1.1 Circular economy and design principles

Nowadays, the parallelism between the circular economy and design principles is fully assumed. The design is a relevant part of several processes aimed to narrowing, slowing down and closing loops accordingly to circular economy principles (Clift, 2015).

For the first time, the user is accepting that their activities and the activities of the society are having a negative impact on the planet's resources and is demanding a change in the global economy.

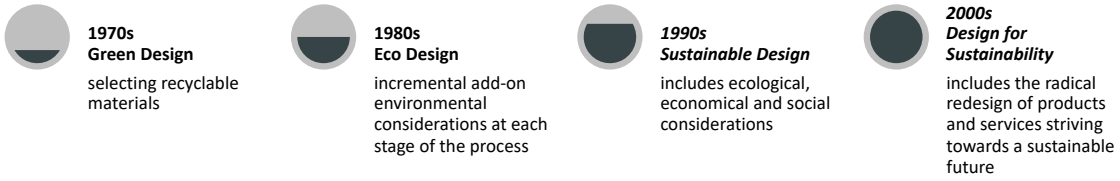


Figure 3. Historical evolution of environmental philosophies applied to design
Based on: (Moreno et al., 2016)

Design is recognized in the literature as a catalyst that promotes the transition from linear to the circular business models, moving away from *take-make-dispose* and installing a more regenerative and circular economy. Figure 3 above, represents the main moments of the historical evolution of environmental philosophies applied to design (Moreno et al., 2016).

The circular approach involves the end-user more than ever (societal vector of the sustainability), especially in the elimination of waste. However, user awareness and contribution in a wide range of product life-cycle phases, or even by maintaining a more direct relationship with the manufacturers of the products (online shopping), is setting a rising trend of direct participation in the transition to circular economy. The next section briefly explores the contemporaneous sentiment that has been rising in a modern consumptive but also highly aware society.

From the business point of view (economical vector of sustainability), the circular business-models are being invoked but as yet they are not widely practised. Today's world lives beyond large changes with topics such as industrial symbiosis, zero waste goals, non-energy industrial raw materials and bio-waste, that influence all activity sectors, as well as people's day-by-day lives. The manufacturers of plastic packaging broached later in this study, are one of the industries that suffer great fluctuations in the environmental and social paradigm.

From the environmental benefit perspective, once product specifications are being made, only minor changes are usually possible. Therefore, it is important to integrate circular

economy principles in an early stage of the design process (Espada, 2020). Ultimately, from general design parameters, innovation in products has to emerge, taking into consideration human aspirations and concerns – answering to a more participative, more environmentally-conscious and more demanding end-user (Charter, 2018).

It is crucial to understand and generate guidelines that will draft future recommendations to product design in general and in particular for the plastics industry. The transformation occurring in the design processes no longer focuses on a product development level as the circular approach requires designers to consider downstream and upstream requirements; on a system level (e.g. material selection, manufacturing efficiency, retail); and on ecosystem level (e.g. co-development, collaboration during life-cycle with partners form other economic activities). Therefore, it is fundamental to look at the considerations of circular economy principles, that should be integrated in an early stage of the design process and understand how it impacts the value chain and the life cycle of the product and services.

1.2 Narrow, Slow and Close loops in the role of design

Nowadays, more and more designers, citizens, businesses and governments are showing a growing concern for environmental pressures related to the scarcity of global resources due to human activities and social and environmental impacts of a consumer society. The current economies and their systems of production and consumption are stressing and damaging the Earth's natural systems. Huge amounts of raw materials and energy are used to create billions of products in order to sustain people's quality of life and consumer habits. At the same time, large volumes of waste are sent into the atmosphere, water, land, ecosystems, which are vital to human existence.

There is a correlation between wealth and pollution and with current technological developments and the multidisciplinary approach to design, an effort must be made to provide product and service solutions that enable the user's convenience while preserving the environment. The underlying problem lies in the current linear economies that make abundant use of raw materials and natural resources, consume energy and waste large amounts of material which ends up as waste. This is immediately followed by new extractions of virgin material with high financial, economic and social costs.

Circular strategies aim to keep the value of resources (Figure 4) and products at their highest value for as long as possible, and to extend their lifetime for a prolonged period of time. These circular strategies aim to: "Narrow", "Slow" and "Close" product resource flows (Bocken et al., 2016).

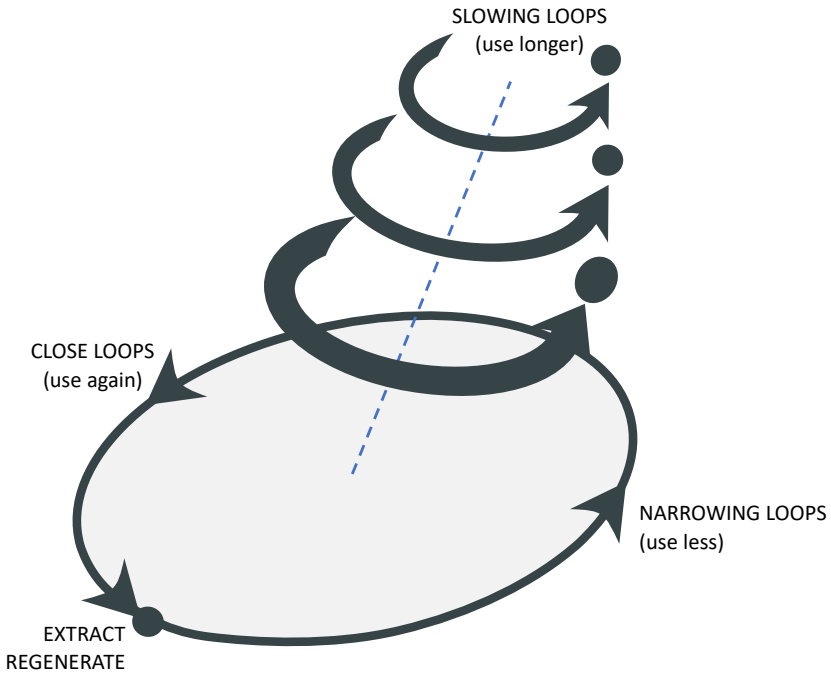


Figure 3. Effects of the circular strategies into the usage phase.

In order to retain the value of the products and resources for as long as possible, it is necessary to create products and services that have a long life span, but moreover, designers are expected to ensure that end-users will use these products for a long time and eventually repair them.

The *narrowing loops* strategy reduces the amount of material per product or service, currently, in the linear economy approach. As the motivation of the companies is cost reduction, narrowing loops are already applied as resource efficiency strategies. From the point of view of design, it can be related, for example, to weight reduction or form flexibility.

The limitation of this design strategy is that it does not necessarily contemplate the end-of-life consequences, recycling, collecting or dismantling strategies (Bocken et al.,

2016). In fact, in the current linear economy, even the products produced very efficiently and according to the narrowing strategies, are thrown away after a single-use.

Narrowing loops can be achieved through using fewer resources in the products, such as lean manufacturing activities which constantly optimise the efficiency of production processes. This can also be achieved through the reduction of the weight in automotive industry, optimising in the production phase through the materials and processes and during the use phase by the reduction of fuel consumption. An interesting business model innovation of narrowing loops is, in fact, the combination with other strategies, for example, moving from ownership of a car to usage of a car that provides a mobility service (Blomsma & Brennan, 2017).

The challenge that designers face to narrow the loops, is to make sure the product and services are developed to increase its durability. This can, however, increase the amount of materials required for production, so there needs to be a trade-off between durability and resource efficiency in production (Bocken et al., 2016).

An LCA can help designers take the right decisions and predict different scenarios before considering the final design solution. For example, design products that are easy to repair, maintain, upgrade, refurbish and remanufacture; using modularity platforms; dismantling readiness or single layer materials, may be some of the strategies where the use of more resources in production can be offset by the longer-use cycle of the product (Manninen et al., 2018).

The *slowing loops* strategy supports continuous reuse over time, and it involves innovation at the business model and value chain levels. Through the design of long-life goods, product-life extension and service loops for repair and remanufacturing, it is possible to slow-down the resources used by intensifying or expanding its use (Bocken et al., 2016).

TU Delft experimented with a business model innovation aiming to slow consumption, giving customers an incentive to reduce the impact of home appliances. Consumers pay per wash rather than buy a washing machine. High quality washing machines last longer and are built to be reused and recycled. The user is encouraged to do less and to wash at a lower temperature, by paying when they use if wash at high temperatures (Bocken et al., 2016). Another example is the Patagonia advertisement in the New York Times: “Don’t buy this jacket” trying to create awareness for ‘slow consumption’.

Considering the narrowing, the slowing and the closing of the resource's loops, the slowing strategy is the most difficult circular strategy to implement. Due to the need for several changes in the design, in the manufacturing processes and in the use phase, which represents an expressive level of uncertainty and risk for business. Nevertheless, it is also the most important strategy because it decreases the amount of resources in the loop and consequently the amount of waste to process and recycle. The recuperation of these resources to remanufacture or reintegrate in a new manufacturing cycle also reduces the dependence on raw material (e.g. mining, fuel resources).

The *closing loops* strategy after several cycles of use, is the concept introduced by Braungart and McDonough in *Cradle to Cradle* (2010). The most relevant design constraint is the use of single-layer materials, since non-mixed or blended materials significantly simplify the recycling process. Design strategies of disassembly and reassembly will be instrumental in closing the loops.

In the plastics industry, paper and metals, recycling rates are already quite significant. Recycling makes it possible to reduce the amount of waste that goes to landfills (or are dumped in the sea) and reduces the extract of exhaustible resources. However, designers play an important role in the narrowing strategy (as will be discussed in the next chapter). Because, if value chains and business models analysis become part of the design process from an early stage, the products and services do not become "waste" in the first place and are instead recovered or recycled (Blomsma & Brennan, 2017).

It is important to note that the transition from a linear economy to a circular economy is much broader than intervening in resource flows. This evolution will have to be supported by new policy, new business models, transformations in human behaviour, and by the development and implementation of strategies for the circular design of products and services in order to build a circular society.

Waste-free design, accordingly to circular principles, can help ensure that we secure enough resources for our societies to develop. This need to combine environmental, social and economic vectors of sustainability may be considered from different perspectives, but the literature shows some common grounds.

Design for circularity requires planning for the entire life cycle of a product and service, and its environmental and social effects. This requires that tools such as LCA, as

mentioned above, should be an integral part of the design project. The design constraints should be established to ensure that (Gorissen et al., 2014):

- future public health and safety are not compromised;
- the environment and resources are not subject to physical and chemical deterioration;
- the after-use of the site is beneficial and sustainable in the long term;
- any adverse socio-economic impacts are minimized, and
- socio-economic benefits are maximized.

1.2.1 Design is key to enable circularity - a system approach to reuse, repair, share

"Form follows Function"(Sullivan, 1922) – Although function adds complexity to design solutions, it is also where most of their value lies. The complexity of circular design derives fundamentally from the system approach that requires innovation and therefore, changes in the existing patterns and habits, in the behaviour of producers, as well as consumers. Design as a multidisciplinary, user centred activity, can establish the interactions between the stakeholders and digitization and new technology allows designers to develop products and services which did not exist before, thereby managing products more sustainably through reuse, repair and sharing.

Design-for-repair and Design-for-recycling are some of the design-strategies, that by definition, integrate circular economy principles at a very early stages of product design.

Complementary to Design strategies for Design for Repair and Design for Recycling, modular platform methods can maximize the functionality of products and their materials. In addition, it facilitates whenever possible the substitution of materials by others that are less scarce or have a less environmental impact, performing a similar function. Dematerialization is also a fundamental variable to be considered at an early stage in the design process (Alaerts et al., 2019). Rethinking the products as a *product-service solution* can result in a total or partial dematerialization of some products and commercialize them as a service or a product with a complementary service, for example the streaming of music that replaced the CD. The circular economy demands the inclusion of the evaluation and development of new business models in order to transform circular strategies into competitive advantages, company resilience and successful revenue models.

Today's business models focus on sales, while cost reduction and the integration of longer use or the reuse of products are not the drivers of business (Pardo, 2018). It is necessary to embrace a new mindset and generate value differently.

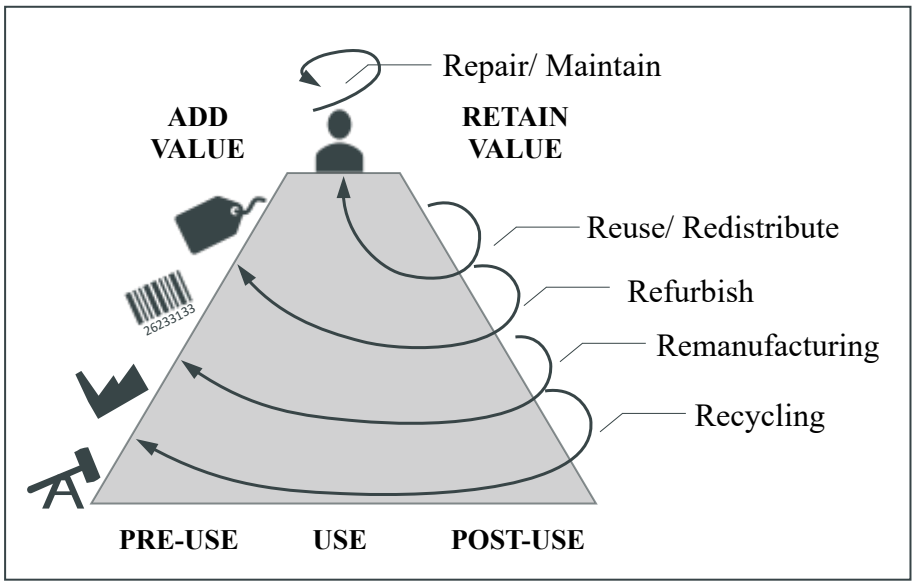


Figure 4. Added value and retained value in circular economy

Based on: (Coursera, 2020)

Figure 4 represents the creation of value according to the circular principles. The left side of the image represents the pre-use value creation and it is similar to the current linear business model. In the centre, is the user phase, in which the value is generated through repair and maintenance. On the right, in the post-use phase, several strategies are represented as retain value strategies. For example, reuse and redistribution retain value for the user; refurbishment retains value in retail; remanufacturing adds value to the consumer-goods producer; and recycling retains value for the manufacturer. It is required to embrace a new mindset, shifting from our current take-make-dispose discourse to a circular vision.

Accordingly, to Jeroen Gillabel, Innovation Team Leader for Sustainable Material Manager at VITO, the 3 key ingredients that any circular business model should ideally have are:

- to engage in some form of circular value creation. To include one or more ways to close, slow or narrow resource loops;

- to make use of value propositions that enable circularity. This depends on the needs and motivations of the customers;
  - Circular branding strategy, when the customer is environmentally sensitive;
  - Premium brand strategy, products that last a lifetime;
  - Product-service strategy, where a company owns and delivers the product as a service instead of selling it;
  - Reducing costs to the customer, when a cheaper product or service is offered, providing a platform to share underutilized capacity, or eliminating product stocks by production on demand;
- to be surrounded by circular value network, when all stages of a product life cycle are connected in a way assuring that the product and its resources are maintained inside the economy. Value networks can be established with several purposes:
  - A deposit refund scheme improves the return of goods to the producer;
  - Online platforms can be used to manage the movement of goods in a network;
  - Setting up a value network at a local scale can help avoid the loss of resources in complex global value chains.

These 3 values will be used further in this study as a framework to develop the scenarios that will aim to demonstrate how designers can define the constraints of the design project, reducing uncertainty and supporting communication with the team members.

In sum, circular value creation are recommendations at a business model level that suggest the use of one or more strategies to close, slow or narrow resource loops. Several strategies were identified in this chapter, such as recycling, repairing, remanufacturing and reusing. The next chapter is dedicated to introducing background information from the literature, specifically from the plastics industry which is scope of this study.

Synopsis of chapter 1

Chapter one provides a brief historical analysis that relates to industrial ecology and design principles. It relates and makes a parallelism between the circular economy and design principles.

The chapter stresses how crucial is to understand and generate guidelines that will draft future recommendations to product design in general and in particular for the plastics industry. And that the design processes no longer focus a product and service level. In a

circular approach designer are expected to consider downstream and upstream requirements, on a system level (e.g. material selection, manufacturing efficiency, retail).

Additionally, it is discussed that circular strategies aim to keep the value of resources and products at their highest value for as long as possible, and to extend their lifetime for a prolonged period of time - "Narrow", "Slow" and "Close" product resource flows.

Finally, three key elements that any circular business model should ideally have are presented: i) to engage in some form of circular value creation; ii) to make use of value propositions that enable circularity; iii) to be surrounded by circular value network.

2. ANALYSIS OF BACKGROUND INFORMATION – SUSTAINABILITY VECTORS

Even though the industry has an important role in the transition to a more sustainable behaviour, educated consumers will be key to initiating the transition from a linear to a circular economy.

Product design role is also fundamental to integrate the principles of the circular economy at an early stage in the design process. Small changes made to existing products serve a linear economy but no longer fit into the philosophy of the circular economy.

The ease of producing plastic packaging has resulted in a significant increase in waste generation, leading to new constraints in the product development process. But these changes, accordingly to the circular economy principles, require an additional effort of plastic packaging producers, when comparing to reduce the package weight and thickness (narrowing loops – linear economy). In this chapter the three vectors of sustainability are discuss and the historical background of the plastics industry packaging is given.

2.1 Societal transformation: design as source of innovations

Circular design is an extensively used philosophy nowadays, and widely acknowledged as the development paradigm still to be followed. It is clear that circular design cannot be regarded just as an environmental statement to the extent that economic and social issues are closely related. A change of mentalities and behaviour is needed, basically in what concerns the consumption patterns that are implied in what is still today understood as quality of life, if circularity is to be attained (Ellen-MacArthur-Foundation, 2015).

With respect to generators of design constraints, it is the user that is the ultimate carrier of uncertainty and the user can delay the adoption of innovations carried to the market within the circular economy. Woudhuysen (2011) discusses that it is necessary to distinguish between the user's subjective perception of change before it becomes reality, and before its implementation. Nevertheless, the success of design solution breakthroughs does not directly depend on users' perceptions of change, but on its acceptance when it is massively distributed. On the other hand, in citing Lord Keynes in Cities for a Small Planet, Richard Rogers (Rogers, 1996) puts forward the argument that it is much easier to introduce a radically new idea, rather than to exempt from an old one.

This argument is, however, sometimes counteracted by that in which it is believed that users accept new ideas but need some continuity to push them softly to change. In this way, the radical or disruptive discontinuity makes things difficult or impossible to implement (as will be discussed further, in the chapter 5). Whatever the prevalent idea is, and from a design point-of-view, this resistance to change creates a momentum to identify the future windows of opportunities and to simulate usability contexts that may shed some light on the reaction to a given innovation – the circular approach at a product, value proposition or at business model levels.

Design for circularity is necessarily subjective because it reflects human value – the relative importance stakeholders assign to the activity to be sustained, to the perceived benefits of that activity, and to other values "traded-off" to sustain the activity in question (Tester, 2005).

Additionally, the fact that the circular economy is a long-term issue and the effects of non-circular behaviour are often delayed in time, influences companies to focus their effort on near-terms issues and avoid problems that are not imminent. However, many companies are becoming increasingly conscious of the need to change their practices.

In fact, the environmental strategies of companies have been evolving over time. The first strategies to be introduced were of compliant nature, i.e., strictly related to environmental regulation and pollution control, and were therefore process-oriented. In order to assess compliance, these strategies made use of tools such as energy and environmental audits. Improved strategies have arisen with extended environmental consciousness and product responsibility, introducing life-cycle thinking. The focus of these strategies is on products/services and on the minimization of the environmental impact throughout their life-cycle, i.e., from the extraction of material to final product disposal, passing the use stage. Life Cycle Assessment (LCA) is an assessment tool of the environmental performance of the product or service that accounts for all the relevant flows of energy and materials (Ferrão, 2007).

Design for sustainability emerges in this strategic context as a life-cycle thinking design approach in which the design goals are those of minimizing the consumption of resources, minimizing emissions and facilitating the disposal of the product at its end-of-life, ideally with good prospects for reuse and recycling. Life cycle assessment is the preferential tool for assisting the design for the sustainability process.

Finally, it is necessary to mention that the most recent and holistic environmental strategies are those based on industrial ecology. These strategies are aimed at closing loops in industrial ecosystems, namely by promoting exchange of wastes across industrial sectors and energy cascading utilization and are therefore system-oriented.

When designing for sustainability, a large number of actors may be involved in the process and that will imply mutual understanding of problems and the identification of common interests and possible synergies, the mutual exploration of different solutions and finally, defining and fine-tuning a common objective. In the process, opportunities for innovating, while delivering more environmentally responsible products, are most likely to occur.

Increasingly, there is a growing cluster of customers that are willing to pay a small premium for environmental friendly products, and this is a great incentive for companies to increase investments in the research of new technological solutions and production practices to better understand life-cycle aspects (Tester, 2005) until design for circularity is a generalized practice.

Accordingly, even though the industry will be an important player in any transition to more sustainable behaviour, many of the driving forces will have to come from a more aware and more demanding customer – educated consumers will be key to initiating the transition from a linear to a circular economy.

As introduced in the previous chapters, the resources are fundamental in the circular economy philosophy. Therefore, the relevance of plastics for the transition to the circular economy, will be introduced in the next section of this chapter.

2.2 Environmental relevance and controversy: plastic as a circular resource

The confrontation with a continent-size patch of garbage composed mainly of plastic floating in the Pacific Ocean produced the anti-plastic sentiment among our modern consumer society. It highlighted, in fact, that much of the discarded plastic packaging is not actually reused or recycled, but rather disposed of in landfills, ending-up in the ocean and other waterways, provoking large-scale damage to Nature (Clapp, 2012).

The user is now a relevant stakeholder of the value chain. Today's user is more informed, more participative and aware that they can make the change happen. The user is now a relevant stakeholder of the value chain. Within a short period of time, it has become

socially unacceptable to use disposable single-use plastic (e.g. shopping bags), and the number of countries where it is now illegal to distribute shopping bags for free is constantly increasing. Environmental awareness has grown around the world, and the well-known anti-plastic sentiment has been encouraged. However, as Clapp (2012) indicates, "The change in norms has been both rapid and globally significant. But as regulatory initiatives spring up worldwide in response to the shifting public sentiment, representatives of plastics industry have resisted these measures" (Clapp, 2012).

"The anti-plastic sentiment is distracting us from the net environmental benefits of plastic relatively to alternative materials when properly recycled" (Selke, 2018). Replacing plastic with alternative materials such as paper and cardboard, glass, steel, aluminium, textiles, rubber, cork, results in a significant net negative environmental impact (Selke, 2018) (Chalmin, 2019).

Despite the anti-plastic sentiment, plastic is also crucial as a circular resource as, for example PE, melting temperature is between 100°C and 130°C, while the melting point of glass is about 1600°C. On the other hand, if we look at paper and cardboard as an alternative, the level of water consumption during the first manufacturing and after recycling manufacturing is extremely high.

A Portuguese collaborative platform, the Portuguese Plastics Pact (*Plastics Pact*, n.d.), joint several stakeholders in the national plastics value chain to achieve a set of ambitious goals by 2025. This platform is led by the Smart Waste Portugal Association, which aims to contribute to solutions associated with plastics pollution at its source; to develop knowledge; and implement actions; towards a circular economy of plastics.

This is one example of the multiplicity of organizations and initiatives, that globally support and work aligned with the Ellen MacArthur Foundation's, *New Plastics Economy* global vision of a circular economy for plastics (*Global Commitment*, n.d.), in which plastics will never become waste or pollution.

Stuart Foster, CEO of Recoup emphasizes how crucial it is to the plastics industry, to approach plastic as a circular resource: The use of recycled content is an automatic requirement, not a choice within a circular economy and we need to see significant progress in the use of recycled plastics in manufacturing (Foster, 2018). These observations raise some issues about the fundaments behind the anti-plastic sentiment and the ethics regarding

the communication being done. Air pollution and water scarcity may be a more serious problem to deal with (Ragaert, 2019).

To look at the circular economy as a simple closing of the loop *take-make-use-recycle* may not be enough. The Single-Use Policy (European Commission, 2018b) demands 90% of the separate and collect target for plastic bottles by 2029 (77% by 2025), as well as the target to incorporate 30% of recycled plastic in all plastic bottles as from 2030 (European Commission, 2018b). Furthermore, Annex III of the European strategy for plastics, set the target of 10 million tonnes of recycled plastics being reintroduced into products in Europe until 2025 and 4 million tonnes in 2016 (European Commission, 2018a).

The controversy is that, to increase recycling after use has often been highlighted as the main strategy to scale up the circularity of plastics, but the industry has no demand for all the recycled material (Wiesweg, 2019 and Ragaert, 2019). The challenge is for the market to absorb all this capacity that nobody needs. Even when referring to polyethylene terephthalate (PET), which is already 100% recycled, it is expected to take more ten more years to close the loop. As a result, all the stakeholders of the value chain need to change and adapt their business (Wiesweg, 2019).

The relevance of this research is described in the graph below (Figure 5).It illustrates the distribution of polymers used, per sector and per polymer type (PlasticsEurope, n.d.).

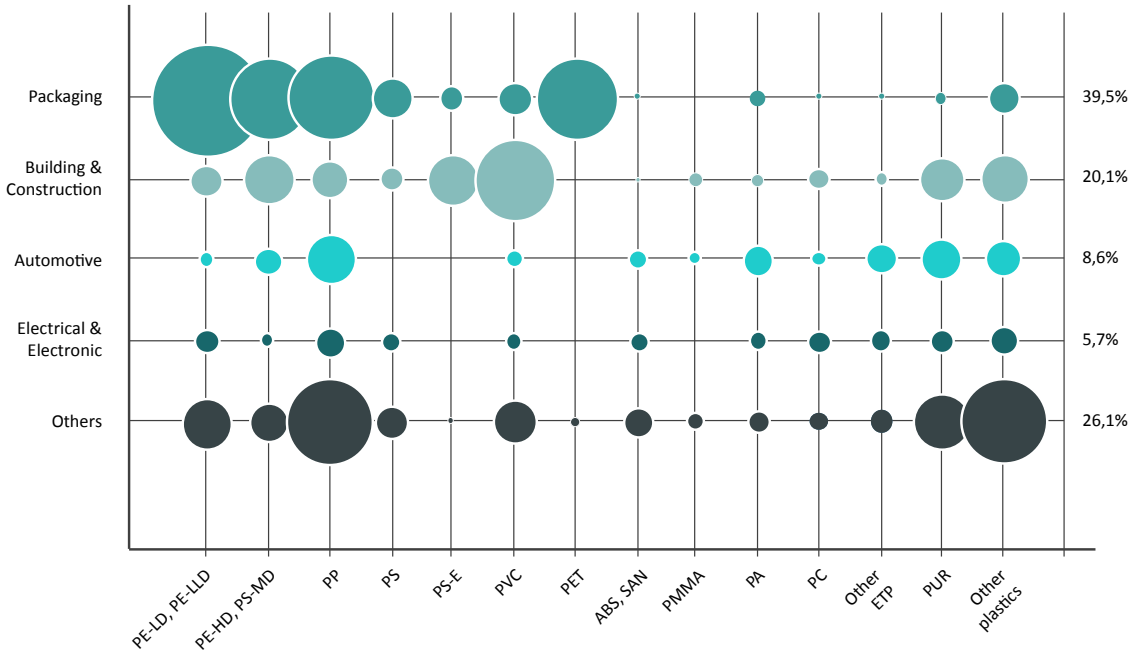


Figure 5. Plastics demand per sector and per polymer type

Adapted from: (PlasticsEurope, n.d.)

The predominance is evident, not only in packaging but also in the use of low and high-density polyethene (PELD and PEHD consecutively), polypropylene (PP) and polyethylene polyethene (PET). This subject will be further discussed in the next section as part of the framework of this study.

2.3 Business competitiveness: waste-free design foundation

To find the implications that can occur in the transition from a linear to a circular economy, it is important to understand what the new opportunities and challenges are at various levels (Bocken et al., 2016). These include the product level (e.g. geometry, patents), system level (e.g. factory, stakeholders, business model) and radical innovations which impact on an ecosystem level (e.g. city, country, policy).

At the product level, it is essential to integrate the principles of the circular economy at an early stage in the design process. Small changes made to existing products serve a linear economy but no longer fit into the philosophy of the circular economy.

At the system level, companies face the transition to a business, which creates monetary and environmental benefits, focused on increasing resource efficiency, ensuring that the value of products, materials, and waste is maintained.

Furthermore, the ownership obligations of plastic manufacturers require that the company's role does not end with the sale of the product. User involvement is critical to the recovery of end-of-life products, thereby promoting corporate accountability and ensuring the reliability and durability of the products produced.

At the ecosystem level, designers and manufacturers are challenged with concepts such as Waste-Free Design, or Zero-Waste Design, aiming to solve the problem of the excessive amount of waste (e.g. including recycled, single-use plastic). The digital technologies such as AI, IoT, Big Data, make possible new and innovative system approaches and design solutions. The integration of products and services; a close relation between manufacturers and users, demand business models transformations facing changes in a city, country and global levels.

In a value proposition of a circular approach, a combination of product and service elements are offered to the customer and can completely change the company's offer. In the music industry, for example, companies such as Spotify have added value to its customers by offering the service of listening to music without ever having to produce, distribute and use a CD. Such models are not new at all and other examples include libraries, cable tv, classical electricity contracts, etc.

However, with the advent of digital technologies, it has become increasingly easier and more interesting to follow a product-service strategy for a wider range of products. Design for circularity is a source of innovation and a unique selling proposition (USP) for business, that can urge manufacturers and designers to provide packaging, which is reusable several times before disposal, thereby preventing the single-use of plastic.

2.3.1 The evolution of plastic packaging produced by insufflation

The industrial revolution (19th century), the consequent exploitation of synthetic polymers at the beginning of the 20th century and after the 2nd world war the increase as a means of containment and distribution of goods, confused the concept of packaging produced by insufflation and blowing (technologies discovered in 1938 and explored only in the 1960s). The current development model, in order to respond to continuous needs that have emerged, and because it is based on successive improvements, has led to packaging concepts that are incapable of responding to the new challenges, particularly concerning the

optimisation of environmental and social resources, and not only those that are economic or functional (Espada, 2020).

The mystification of plastic packaging production from insufflation has resulted in a significant increase in waste generation, leading to new constraints in the product development process. In this sense, the Research and Development (R&D) effort of plastic packaging producers has fallen primarily in reducing the package weight and thickness.

2.3.2 Centralised production

The decentralisation (Figure 6) of plastic packaging production (or in-hole production), by opposition to the centralised production, was a natural consequence of the regulation, mainly to avoid the contamination which occurs during transport, and pre-filling of packaging with alimentary products. However, the sustainable concepts have been generalized widely, and for market segments with less anti-contamination restrictions, such as house-care and healthcare, centralised production is still a common scenario nowadays.

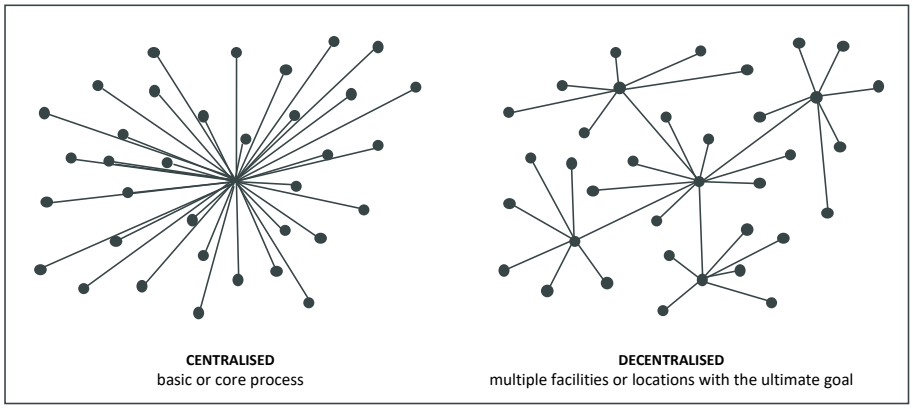


Figure 6. Centralised versus Decentralised (or in-hole production)

The environmental impact on the transportation of empty plastic package, associated with carbon emissions and fuel consumption is significant. Nevertheless, centralised production has many benefits when compared with decentralised. According to the American Productivity & Quality Center (APQC), controllable manufacturing costs are 10% lower at centralised companies compared to decentralised ones (Bililies, 2016).

An APQC study, has demonstrated that the costs of centralised production when compared with the cost of a company following a decentralised business model, are about 3% lower (Bililies, 2016).

Digitalization of business is addressing many of the limitations of decentralisation, and business is being transformed by digital technologies and Industry 4.0 principles (Dalenogare et al., 2018). Nevertheless, centralised structures can potentially still offer cost reductions. Hybrid circular business-models can support the redefinition of the business competitiveness, avoiding high risks and spreading the investments on the transition and smoothing the transition from a linear to a circular economy.

In addition, for such a low-cost product, bleach, packaging, and transportation make a high contribution to the final cost and retailing price. Centralised production is likely to be a business model operating in the future. It is relevant that designers explore new solutions that meet the current philosophies of the circular economy, since the technological and material sciences have undergone a rapid and profound development which adds more possibilities to the state of art that were not possible when decentralised production expanded (Golding, 2016).

To better describe the contribution of design to define these new circular business models, an example of a WisePack design solution will be presented in the next section. WisePack explicitly addresses the problem of effective environmental costs in transportation, storage, and collection of blow-moulding plastic bottles.

In a centralised business model, the volume of the packaging during transportation and storage before the filling process represents the largest parcel of the cost per unit. Nevertheless, centralised production is still a current practice when the product to be packaged, has a market value inferior to the production cost of the bottle (e.g. bleach). The following section aims to explicitly exemplify how design can address the cost-effective and environmental issues of blow-moulded plastic packaging produced in a centralised business model.

Synopsis of chapter 2

Chapter two, is an introduction to circular design. Topics include eco-design, methods to assess environmental impacts, and collaboration networks. Basic concepts are introduced, such as centralised and decentralised production in the plastic packaging industry and plastic as a circular resource.

3. RESEARCH METHODOLOGY – APPROACHES, METHODS AND TOOLS

After identifying the gap in the literature and the controversy on the subject, a primary historical background was conducted, namely related to the design and the environmental philosophies over the years. This approach is a research strategy that concentrates on understanding the dynamics present in facilitating the definition of the conceptual framework, concerning the systematic circular approaches into the design process.

Based on this preliminary analysis, it is possible to identify the appropriate conceptual framework to define the hierarchizing for case study structuring by the analysis of problems associated with this new paradigm, the circular economy. This will facilitate familiarization with the demands and system complexity of this type of WisePack business, in terms of trends, users, and stakeholders and business orientation, which will be critical for choices in the design process.

The conceptual framework is entitled by system-centred and circular-design (SCSD), and it intends to understand the advantages of the adoption of a circular design framework as well as the potential benefits and archetypes of the circular product value chain.

This interactive process gives feedback to the general value chain typologies of the plastics industry with a centralised production, in order to define theory and detailed knowledge about refill and reuse of plastic packaging. Slowing loops of circular economy strategies, poorly approached by this industrial sector.

Future trends, by applying the ethnographic methodology and recommendations to System- centred Circular Design (SCCD) strategies, result in proposing a conceptual ground to design the future scenario of single-use of plastic packaging.

3.1 Structure and methodology of the study

A qualitative approach was chosen, to analyse the evolution of packaging design concepts along the development loops resulting from the design and manufacturing process.

This option follows Michael D. Myers (Myers, 1999) reasoning that ethnographic research is one of the most in-depth research methods possible. Because the designer is at a research site, contacting and discussing with everyday players on the researched subject and sees what people are doing as well as what they say they are doing – an ethnographer obtains

a deep understanding of the people, the organization and companies, and the broader context within which they work.

Ethnographic research is thus well suited to providing circular systems designers and companies decision-makers, with rich insights (Myers, 1999).

This study outlines the most important issues that need to be considered in selecting these design strategies and define the circular business models in an early stage of product and service design.

According to Sampieri, Collado and Lucio (2006), qualitative research gives data depth and a wide possibility of interpretation, as well as details and flexibility. The choice of different collection resources is due to the qualitative nature of the research and aims to raise information from different angles to understand the constraints and objectives among different stakeholders of the value chain.

To Hammersley (Hammersley, 2016) ethnographic research may be assessed for how well it helps to solve practical problems.

And Margaret D. LeCompte, Judith Preissle Goetz (LeCompte & Goetz, 1982) argue that researcher can solve through design problem with strategies intended to enhance credibility that are incorporated throughout the investigative process: study design, data collection, data analysis, and presentation of findings. Common approaches to resolving various design strategies are illustrated from the interviews with experts in the plastic packaging industry and issues of reliability and validity in the ethnographic design are compared to their counterparts in experimental design.

To ensure that the analysis of the case has a solid academic grounding, the following methodological approach was established by identifying key concepts and theories to guide the analysis and interpretation. It is described below and detailed in Figure 7.

- **Preparation** relating to theory and problem delimitation;
  - a literature review;
  - semi-structured interviews;
- **Exploratory research** to uncover new concepts and ideas that need to be incorporated;
  - collective case study:
    - value chain analysis;
    - circular business-model innovation analysis;

- **Execution** - exploring the design case through exploratory scenarios to verify (or not) the established assumptions;
  - design conceptualization – System-Centred Circular-Design;
  - circular systems conceptualization.

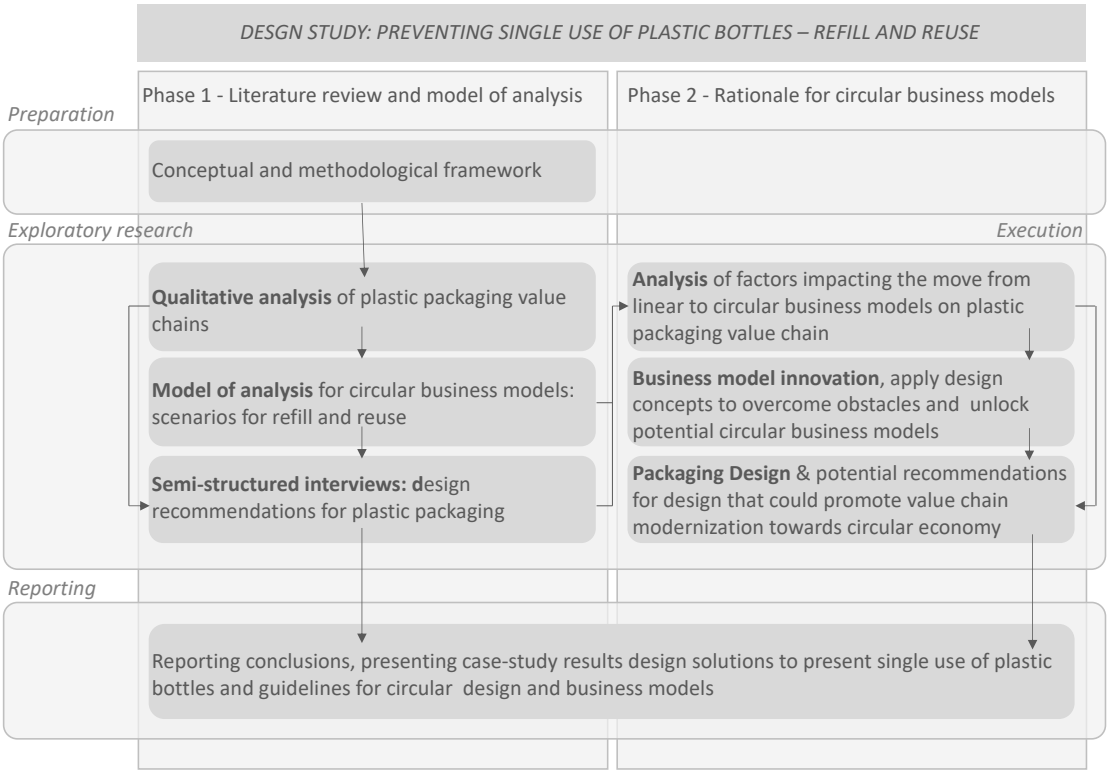


Figure 7. General Plan of methodology application

The first part of the preparation relates to theory and problem delimitation. A literature review was conducted, including a theoretical and historical review and the second part analyses background information according to societal, economic, and environmental vectors. With the focus on meeting the specific objectives of this study and delimiting the research problem, the interviews were chosen as a preliminary data collection technique. Since it is intended to obtain subjective information, the semi-structured interview was adopted (Boni & Quaresma, 2005).

Ethnographic Methodology involves learning from people (or organisations) in order to understand their culture and contextualize their activities. It can involve qualitative and/or quantitative descriptions of human social phenomena and presents the results of a holistic research method founded on the idea that a system's properties may not necessarily

be accurately understood independently from each other. Several academic traditions, in particular the constructivist and relativist paradigms, claim ethnographic research as a research method (MIT Documenting Culture, n.d.).

Ethnography makes use of fieldwork techniques and should be associated with places where people live and work, such as their homes, companies or urban spaces, cities and countries. Researchers analyse these environments to understand, describe, and explain specific cultures and artefacts and the systems that support it. This tool is particularly effective at detecting the meaning that customers attach to products and services and in revealing people's hidden beliefs and values. The specific techniques applied in ethnography are relatively simple, e.g. interviews and direct observation. These techniques may also be pushed to the point in which anonymous potential users are brought into the design process through participation in the construction of scenarios.

3.1.1 Semi-structured interviews

The interviews were carried out assuming a neutral attitude, exempt from value judgments or preconceptions and preserving confidentiality of the interviewees (Guerra, 2006). The role of the interviewees in the companies or institutions, are product development; R&D; innovation; or operations and manufacturing management (Table 2). Accordingly to Boni and Quaresma (2005) and Guerra (2006), the people contacted for the interviews must be able to clearly verbalize the ideas, so that the data provided is useable.

With regard to the preparation of the interviews, a script (Figure 8) was organised with the questions that help to adapt the discourse during the interview.

The *interview script* has been completed over time and the questions were not necessarily asked in order. In order to maintain a fluid speech. However, the objectives and dimensions of the interview analysis were maintained (Figure 8), to facilitate the analysis and interpretation of the data collected (Guerra, 2006). Moreover the *Analytical Grid of the Interview* (Figure 9) is indispensable for that analysis (Boni & Quaresma, 2005).

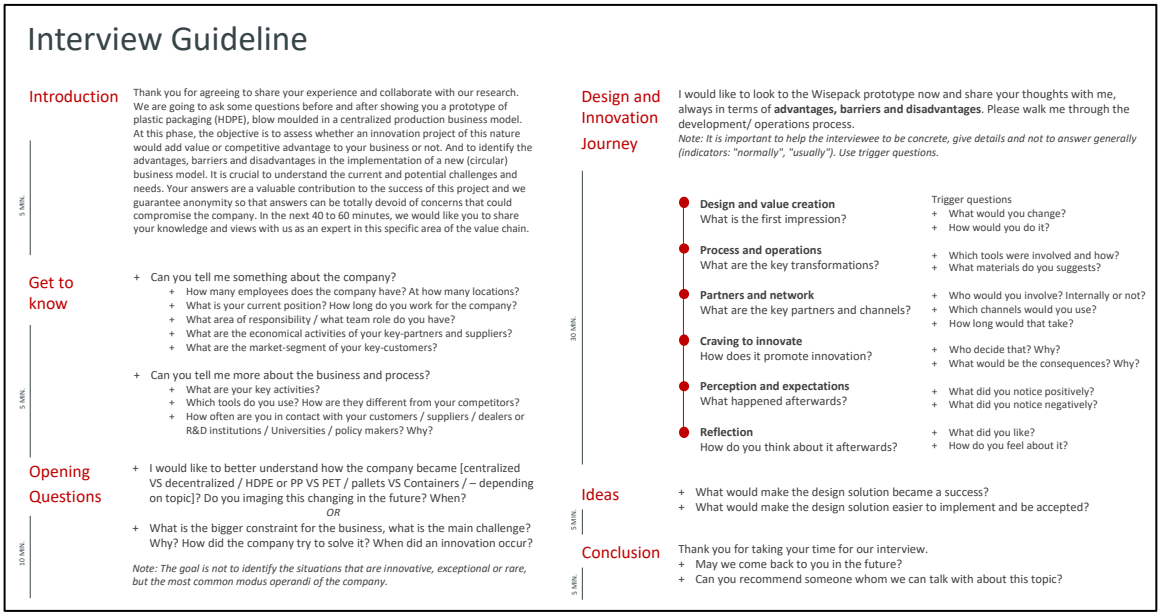


Figure 8. Interview Guide and Script

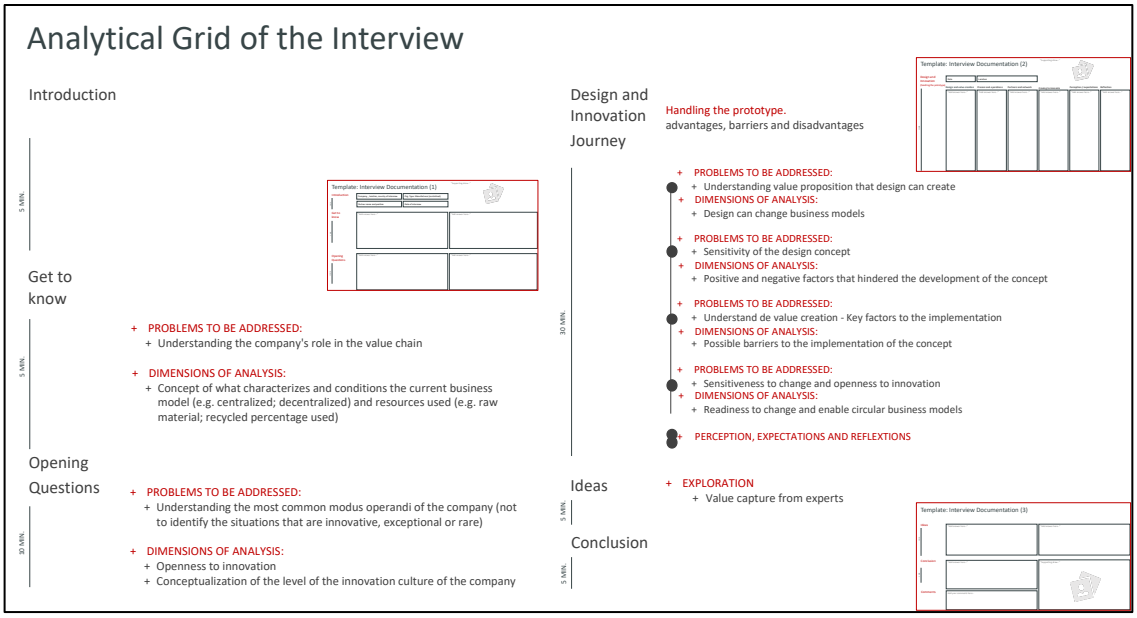


Figure 9. Analytical Grid of the Interview

3.2 System-centred Circular-Design methodology

Project design is a discipline that involves a multitude of actors from different backgrounds, with different attitudes, approaches and methodologies, implying that designers must merge information from each area during the whole process. This design process in constant evolution can be considered as the one that establishes the connection,

in which the information circulates between each area of the project and the different actors involved.

The case study analysis defines the global concept, guidelines and constraints for the design process, leading to a design solution that should embed considerations associated with the product life cycle, from the manufacturing to the disposal stages (with all the different circular strategies that may be implied).

The circular economy and its multidisciplinary intrinsic context allocate a high level of complexity to the design process. It involves several stakeholders and it adds new dynamics to the product live, with strong implications on the company's business models. It is the designer task to manage the process so as to maximize the benefits of integrating competencies while minimizing or avoiding the associated risks and uncertainties.

From a designer point of view, the user requirements are extremely important, even if they are imposed indirectly to the design process. In this sense, design methodologies tend to have embedded a user centrality.

In fact, this is almost intuitive since if a given product or service does not fulfil the user expectations, it will be most probably be condemned to unsuccessfulness, independently of whether the client's expectations are met. Human-centred design as a conceptual framework to the design process was developed to overcome recurrent poor design, by emphasizing the needs and abilities of those who were to use the product. Usability and understandability of products have indeed been improved, but even so, we still have complex and confusing products. Human-centred design has become such a dominant theme in the practice that it is now accepted by designers without questioning, almost dogmatically. However, Donald A. Norman (Norman, D., 2005) suggests and discusses that activity-centred design may be a superior approach.

Nevertheless, in this research, we propose a system-centred design, thereby provoking an emerging discussion regarding some of the fundamental principles of the design for a circular economy. The general goal of this case study is to understand the various stages of the design process for circularity, and to evaluate notation for each process step. These goals are consistent with the analysis process of Bocken (2016) and Kalmykova (2019), considering circular business model innovation and circular value chain, respectively. The case study is based on the reuse of plastic packaging, and design (as a

discipline) supports the development of a System-Centred Circular-Design (SCCD) approach.

3.2.1 Case Study Goals

Designers include the user experiences and expectations with regard to the design solution. These expectations could be more or less extended, based for instance on feedback from previous product-generations or from customers of the manufacturing industry, or even on feedback from all the stakeholders in the supply chain. This more or less tacit, more or less codified body of knowledge (collected from the preliminary interviews) was used to understand and frame the case study analysis to be performed, which in turn determined how it would be organised (Figure 10).

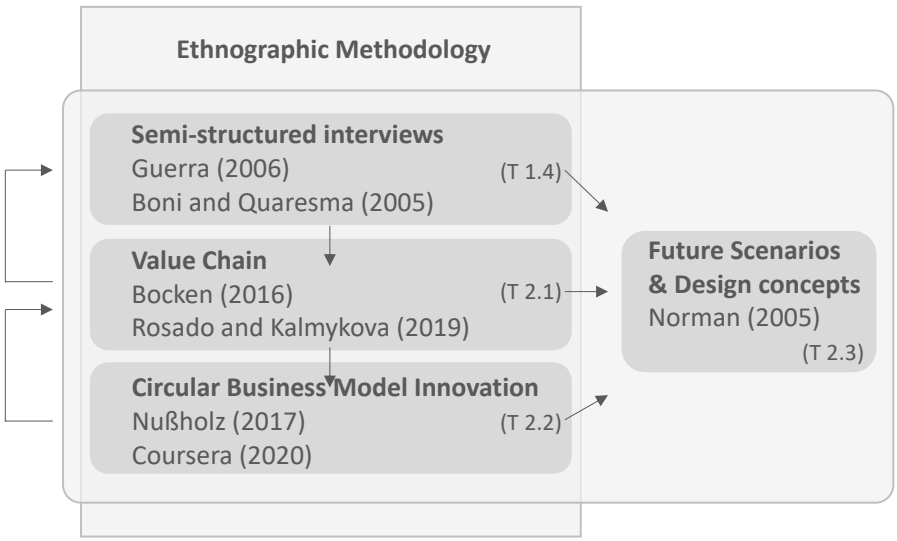


Figure 10. Case study structure and methodologies

The goals addressed in this research entail learning about SCCD. The following secondary goals are intended to understand better the possible advantages associated with the adoption of the circular design framework, identify potential benefits and archetypes of the circular product value chain, and investigate suitable value chain typologies.

3.2.2 Business model innovation methodology

Another secondary goal of the case study is to analyse the business model innovation strategies for the circular economy. This analysis aims to identify product/ service

value flows and primary sources of revenue. The design recommendations to develop a SCCD process for innovation emerge from this methodology to frame the design process in a system-centred approach.

The SCCD is presented as guidelines that support the creation, analysis and execution of specifications and formal process designs. Julia Nußholz (2017) business model planning methodology is applied in order to be able to represent specifications and process designs in a complete and concise manner (Table 4).

In order to evaluate the generated business models simulation, future scenarios are developed, where it contained the characteristics necessary to satisfy the claims made by the system of the analysis. This will drive the research to the execution required to perform a simulated execution of the future scenarios that could prevent the single-use of plastic packaging.

An SCCD, by its systematic nature, provides several concepts for building new and more complex collaborations in the supply chain. This relationship in the circular process defines the design requirements and attributes.

In short, the steps taken on this adapted ethnographic methodology are:

- semi-structured interviews
- product, supply and value chain
- business model value creation and slowing loops
- development of scenarios

Reflection on the research process leads to rich and convincing explanations of its outcomes. As the research continues, new insights will appear on the identification of conceptual guidelines, which will be the main output of the whole process. Scenario construction seeks to build theory, which may be seen as “a system of interconnected ideas that condense and organise knowledge”.

Synopsis of chapter 3

A qualitative approach was chosen, to analyse the impact of the packaging design concepts along the definition of the business models and its circular loops. Chapter 3 presents the structure of the research and the methodologies used. The research is organized in 3 main sections, with respectively sub-sections:

- **Preparation** relating to theory and problem delimitation;
    - a literature review;

    - semi-structured interviews;
- **Exploratory research** to uncover new concepts and ideas that need to be incorporated;
    - collective case study:
        - value chain analysis;
        - circular business-model innovation analysis;
- **Execution** - exploring the design case through exploratory scenarios to verify (or not) the established assumptions;
    - design conceptualization – System-Centred Circular-Design;
    - circular systems conceptualization.

From the literature revie and professional experience, ethnographic research was designated for the study**.** WisePack design solution was selected to analyse the slowing and closing loop. WisePack circular business models' assumptions are described, followed by the stakeholder's interviews and finally, guide the case study analysis.

Based on the semi-structured interviews done to the main stakeholders of the value chain, four factors were defined as relevant to promote the transition from a linear to a circular approach: i) design has a relevant relation on the business models; ii) design barriers to the implementation can impact the value creation; iii) design can influence and change the openness to innovation; iv) business value capture relates to the innovation culture on the current linear business models.

It was found in this exploratory phase of the research is the presented packaging design solution – Wisepack - may have changed some of the assumptions made by the representatives of the different stakeholders of the value chain.

4. DATA ANALYSIS AND RESULTS – WISEPACK PRESENTATION

This study aims to promote a new milieu of discovery, learning, and sharing through the implementation of design practices and a better compromise of circular business models and design-based activities in the plastic-packaging industry. Namely, refilling and reuse in addition to the recycling circular strategy, which seems to be less popular in the market segment of plastic bottles. The ultimate goal of this study is to understand if design can prevent the single-use of plastic bottles for house-care and healthcare market segments; produced in a centralised business model.

The Wisepack study case was chosen to the analyse and reverse of the design process due to be a packaging that promotes a reuse and refill business models due to its geometry, if the analysis verify the assumption, the research findings will answer to the stablished question: “How can design be a source of innovation to transform businesses models accordingly to circular economy principles?”.

In order to focus the analysis of the case study, the project WisePack was used because of two main factors:

- The functional characteristics of the Wisepack package are directed linked to its design;
- The geometric characteristics of the Wisepack package concept facilitate the reuse and the refilling of the packaging, so it allows for the study to be conducted and more realistic results to be obtained when compared with the traditional plastic bottles options whose poor performance for reuse and refilling are well known by the industry and market in general.

These assumptions were confirmed during interviews made to key stakeholders of the plastic packaging supply chain and are presented at the end of this chapter in order to better frame the case study analysis made on the chapter 5.

The principle of WisePack is the collapsibility of the packaging (Figure 11) before the filling phase and after the use. In this way, it avoids the volume of air during transport, its cost and the carbon impacts, as well as facilitates its collection after usage with less contamination, reducing the negative impacts of the washing process. Pollution reduction is possible with the reduction of the amount of wastes generated. This is achievable through ensuring that the packaging material, which is used guarantees the refill, reuse and recycle policies.

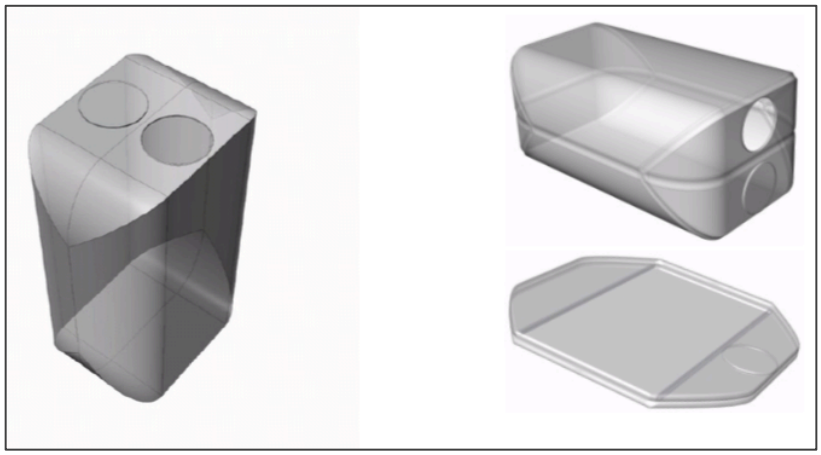


Figure 11. Wisepack collapsible packaging principle
(Source: WisePack archive, 2008)

WisePack geometry includes significant possibilities of change on a level of the business model and value chain. The geometric characteristic of the plastic bottle WisePack is an interesting subject to shape this research challenge (Espada et al., 2008), (Espada et al., 2007).

4.1 Product description

Wisepack design idea was originally patented in 2004 by the designer Luis Vargas, as a Portuguese invention No. PT 102805 with the title “Embalagem colapsável” (Vargas, 2004). The geometry has some mechanical problems and in 2008 an improved international patent was submitted (Espada et al., 2007) with a new design concept in order to reduce and control the tensions involved in the collapsibility of the packaging.

In 2008 the international patent No. WO 2008/020776 A1 was published (Espada et al., 2007) with the title “Method of reduction and control versus tensions involved in the collapsibility of a totally collapsible packaging” and this last version was the one used to support the present research.

The first design solution of plastic packaging when reconfigured into its initial inflated shape, some deformations and ruptures occur in its material that compromises the ability of the package to contain the product. Those deformations are caused by a compression of material that occurs when a package transits from an inflated state to a collapsed (plane) state, and vice-versa.

In the intermediate stage, some of the surfaces (horizontally extruded) gather tensions that contribute to the package's dimensional stability (be it inflated or collapsed). Nevertheless, the intensity of these forces causes plastic deformations which eventually the material is ruptured, compromising the functionality of the package itself (Figure 12).

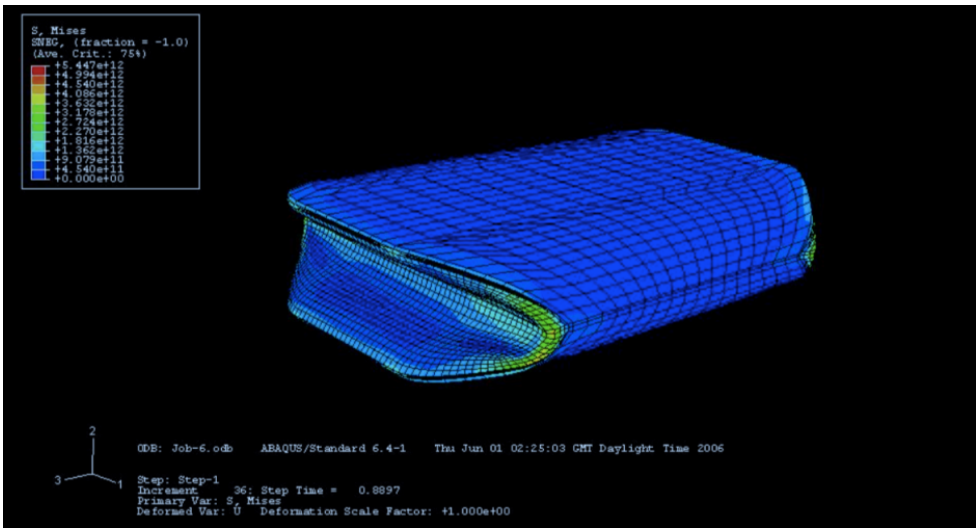


Figure 12. Finite element method (FEM) to analyse the surface behaviour
(Source: WisePack archive, 2008)

The second design solution is able to reduce and control the tensions involved during the collapsible movement. This geometrical configuration (referred to as WisePack) permits the re-operation of the packaging, allowing the optimisation of logistical processes in transport and storage, throughout the package’s life-cycle (Figure 13).

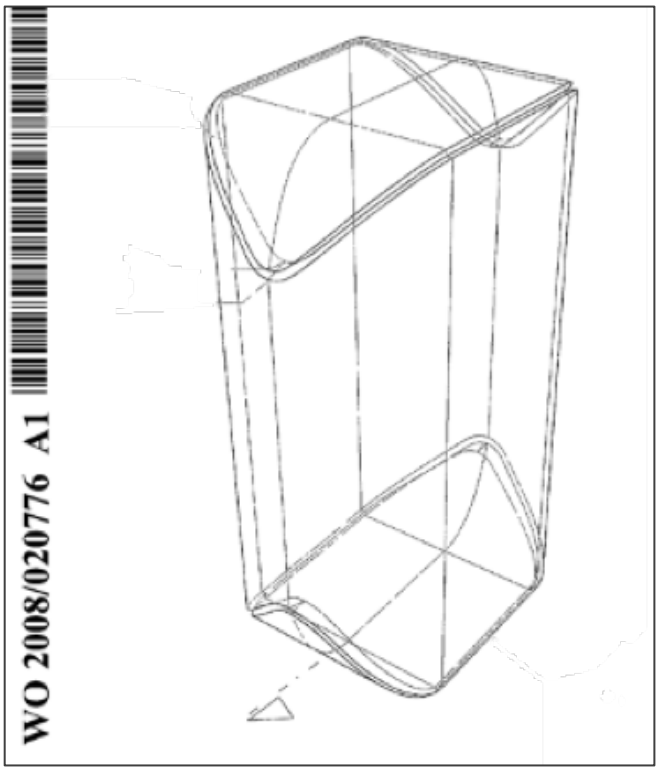


Figure 13. Second collapsible design solution
International Patent No. WO2008/020776 A1

Functionality and technical description (Espada et al., 2007), (Espada et al., 2008):

The geometry consists of a bellows system capable of minimizing the space that a package occupies, assuming a planar and stackable configuration. It is called collapsible to the movements between the position exclusively planar or closed (two-dimensions) and plannable (three-dimensional curved surfaces in a single dimension), filling and usage position.

The flexing lines, which connect the surfaces (Figure 14), acquire an elastic function due to its geometry, capable of sustaining the mechanical transformations undergone by the packaging, without causing ruptures and cracks during several cycles of use. The collapsible attributes of the packaging allow access to the interior to be sealed by a fitting (symmetrically aligned) on the top, capable of sustaining the planar or closed configuration of the packaging and preventing its interior from being contaminated. These characteristics provide the packaging with the ability to be protected and to be refilled or reused.

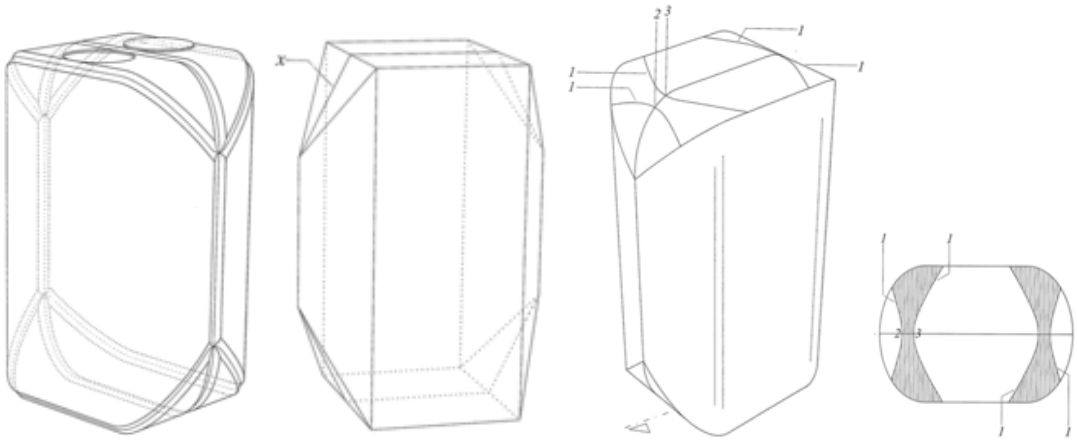


Figure 14. Geometry formula to allow collapsibility of a semi-rigid plastic packaging (Source: Espada et al., 2007)

Most plastic packaging is collapsible. Nevertheless, few designs manage to reduce its volume to the minimum possible, which is, the volume of their own material. Additionally, the existing solutions are based on a classic bellows system, whether it is oriented vertically or horizontally (Figure 15).

Figure 15. Current bellows systems ineffective collapse and damage the package (Source: WisePack archive, 2008)

These orientations of the bellows systems prevent most of the plastic package from collapsing effectively and ending up completely damaging it due to deformations that occur in the material. Making it impossible to refill or reuse the package.

Technical limitation of current solutions which promote the single-use of plastic – WisePack competitive advantage: In most cases, if it is desired to maintain this configuration, it is necessary to use a cover to create a vacuum inside the package. This contradicts the recommendations of recyclers who call for the separation of accessory equipment from the body (almost always made of another material), in order to facilitate the sorting of their waste.

The ability of a package to contain and protect a product does not change after consumption. That is, taking a product off a supermarket shelf, taking it home, opening its packaging and emptying its contents, does not damage the shape or function of the said packaging. However, even in excellent conditions, it is used only once and classified as waste. What was once carefully treated as a tool is suddenly seen as useless. The stress that goes through the collection, transport and storage of waste damages the packaging in terms of form and function. All that can be done with this amorphous material is to recycle.

R**ecycling has allowed packaging waste to be valued, but the amount of waste has not been reduced:** The packaging industry has never hesitated to manufacture disposable packaging. After the Industrial Revolution, with the appearance of the first synthetic polymers, this aspect was so catalysed that it became a serious environmental problem. The advent of recycling allowed packaging waste to be valued, but it was not able to reduce the amount of this waste. On the contrary: the concentration of packaging provides for this disposable and recyclable end of life.

As introduced in chapters 2 and 3, plastic is a privilege circular material, especially when compared with others such as glass or paper. Nevertheless, recycling plastics is a process that does not optimise energy resources: granulating, washing, melting and inflating your material consumes more than washing and original packaging. A large percentage of the waste we produce is packaging. The most environmentally friendly attitude is not to value them, but to prevent them from being produced. For that to happen, the packaging cannot be wasted. Once used, it will have to survive its own use and be refilled or reused.

4.1.1 Collapsibility to reduce the volume during transport

The principle of WisePack allows for a package to be able to collapse in the pre-filling stage. In other words, it will allow that a package be produced in one place, be folded into a small fraction of its volume and subsequently transported to another site for filling.

Another vector in packaging design, geared towards reducing the volume of waste, concerns its ability to collapse in the post-consumer phase. Although some solutions that contemplate a collapsible function, taking advantage of the structural ribs in the packaging body, even if collapsed, the packaging still occupies a significant part of its initial volume (Figure 16). Additionally, the vertical bellows system that provides the collapsible function also implies a considerable increase in the material needed to pack a given volume (zigzag surfaces instead of straight ones) (Espada et al., 2008), (Espada et al., 2007).

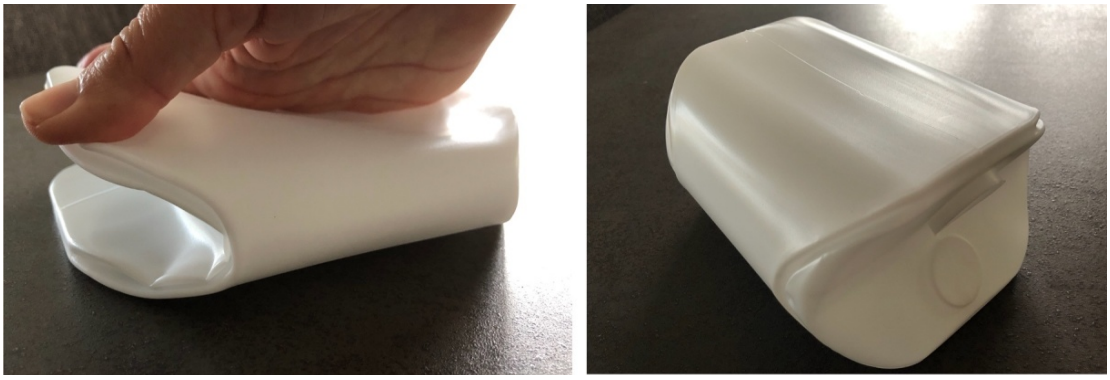


Figure 16. WisePack 1.0 functional prototype (blow moulding, Nov. 2019)

Policies around producer responsibility, add and additional layer on the path to environmental excellence. The overall optimisation of space during transport, storage and collecting stages of the value chain, are possible with solutions that drastically optimise the not only the resources involved in the management of packaging waste, but also when the variable air/volume-reduction is added to de design specifications. This geometric characteristic of Wisepack solutions has direct repercussions on the various stages of its life cycle, namely in the manufacturing, distribution, filler, user, collector for recycling.

To better explain the potential of the volume-optimised design-solutions, two transport scenarios are presented (Figure 17). In a simplified conservative estimation scenario (contemplating fuel costs), to transport the same number of 1-litre packaging waste, the current model will cost 725€/100Km and the Wisepack model would cost 78€/100Km -

minus 14 trips of a long-haul truck. For the 5-litre packaging waste transport scenario this advantage expands to 1 294€/100Km - minus 25 trips). Adapted from: (Espada et al., 2008), (Espada et al., 2007).

The same simplified calculations apply to the CO_2/km emissions of a long-haul truck. To transport the same number of 1-litre packaging waste, the current model will emit 12 600g CO2/Km and the Wisepack emissions would be about 900g CO2/km – for the same 14 trips of a long-haul truck. For the 5-litre packaging scenario, this advantage expands to 22 500g CO2/Km – of 25 trips (Espada et al., 2008).

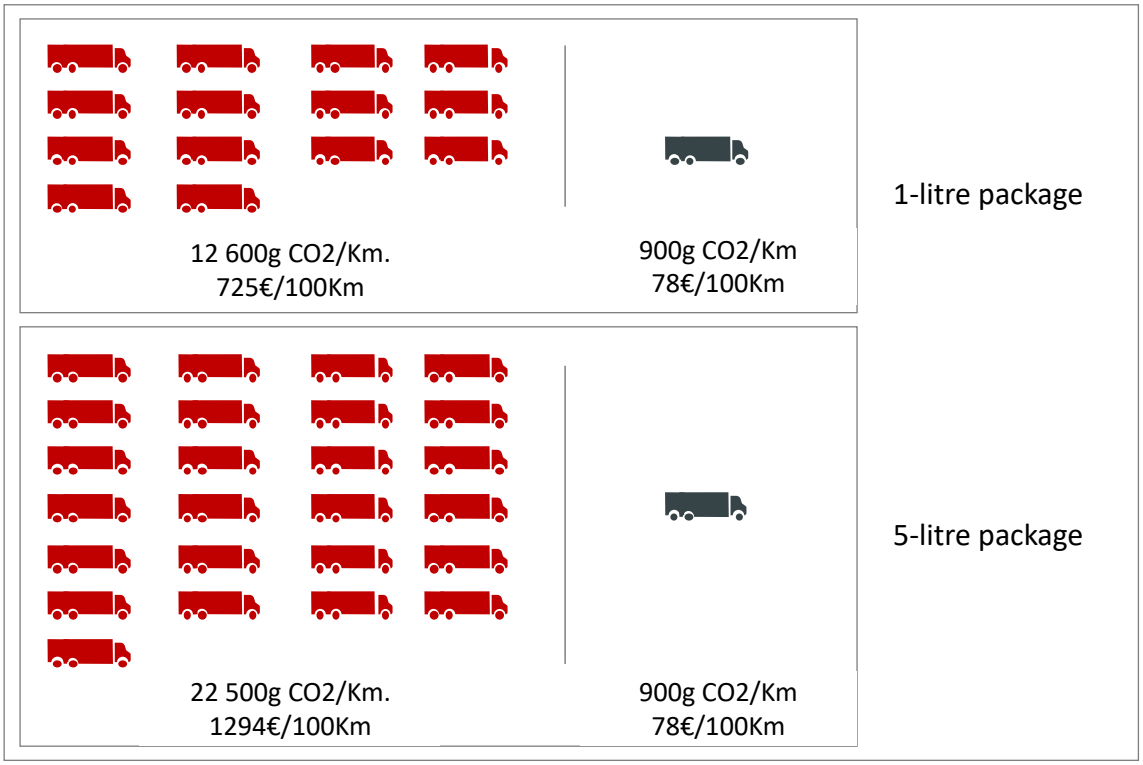


Figure 17. Air volume during transport optimisation: 1 litre and 5 litre scenarios Adapted from: (Espada et al., 2008) (Espada et al., 2007)

A design solution such as Wisepack, which simplifies the user's role in packaging waste management, increases the take-back percentage, but also allows the user to reuse the packaging several times.

4.2 Contextualization of the case study: data gathering and analysis

According to WisePack market approach from the business point of view, the business models for a circular economy can be addressed by design and manufacturing towards different go-to-market strategies. As part of the manufacturer's retailers and collector responsibility, to define new circular business models, three scenarios are drafted – recycling, refill, reuse (Table 1).

As many of other exploratory business models, the scenarios schematized in Table 1, are simply representative of the reflection exercise, based on the business experience. From the academic point of view, it was important to validate these assumptions with non-structured interviews.

It is important to notice that although the interviews are not part of the core analyse of this, they are fundamental to frame the case study discussed in chapter 5.

In this section the WisePack circular business models' assumptions are described, followed by the stakeholder's interviews and finally, guide the case study analysis in the next chapter.

Table 1. Exploratory scenarios to define circular business models

Scenario Recycling (closed loops)		Scenario 1: slow + closed loops		Scenario 2: slow + closed loops		
B2B: Marketing tool e.g. new story for well informed user		**B2G: Re-fill Re-use eco-systems** e.g. Public Org. & HoReCa firms (3 to 5L)		**B2C: Re-fill Re-use Recycle** e.g. Retail stores with non-packaging areas		
Cost saving Why? Transport and storage optimisation		**Cost saving and re-use** Why? Easy to collect, storage and transport		**Cost saving and user participation** Why? Add liquids to the no-packaging areas		
Surface Care e.g. detergents or bleach	**Personal Care** e.g. shampoo or shower gel	**Surface Care** e.g. detergents or bleach	**Personal Care** e.g. shampoo or shower gel	**Surface Care** e.g. detergents or bleach	**Personal Care** e.g. shampoo or shower gel	**Food** e.g. juice, soup

Scenario 0 - Recycling

The first scenario, on the left side of Table 1, refers to the most conservative approach to circularity in the plastics industry. Nevertheless, it is fundamental to take into consideration the manufacturers and fillers (business to business (B2B) that have already made investments according to the decentralised business model. Not only the changes in the production line, but also the organisational structure are good reasons to resist to this transition to the circular economy. Reintroducing recycled material into new products is the fastest change and the innovation insides mostly on R&D on the material and separation levels. It is also an easy message to communicate with the costumers of the filler with short terms impacts on sales (e.g. 100% made by ocean plastic).

Scenario 1 - Refill

The second scenario describes a business to government circular approach. This model is ideal for a pilot phase since the logistics involved in the collecting after use, are at the delivery point and the changes involved to collect the used packaging for refill would be simplified when compared with a separation at a recycling park. In addition, the volumes of sales for governments (e.g. hospitals, schools, universities) and its scalability, are factors that increase the feasibility of the study in a pilot phase and serve as a lever for the development of public policies and recommendations for the industry. The authors believe that consortiums and trans-sectoral collaborations among the value-chain are the best design direction to explore and develop future business models for circularity through design.

Scenario 2 - Reuse

The third scenario may be a medium/ long term scenario due to its difficulty to implement and due to demands for significant changes at all the levels of the value chain. Nevertheless, it is also the most interesting because it combines:

- Refill cycles (B2G and B2C);
- Reuse cycles;
- Recycling after several cycles of refill and Reuse.

The combination of these circular business models would end with the end of life concept, allowing the packaging to last longer and consequentially, reduce the dependency on fuel resources. For each product-design and each business situation, a life-cycle analysis is recommended in order to evaluate the reduction of the environmental footprint along the life cycle.

4.2.1 Stakeholders' interviews

The interviews were not conducted mechanically, and the protocol was used more as guidelines to help outline the research problem. This approach allowed spontaneous follow-up questions to be asked in order to clarify the details of the subject. The interviews ranged from 60 to 90 minutes, and notes were taken during this time.

An overview of the conducted interviews, the titles of the informants, as well as the type and location of the organisation, are shown in Table 2. The conducted interviews were not conducted mechanically, and the protocol was used as guidelines to help outline

the research problem. This approach allowed spontaneous follow-up questions to be asked in order to clarify the details of the subject. The interviews ranged from 60 to 90 minutes, and notes were taken during this time.

The interviews were conducted between August and November of 2019, toked place in several locations of two countries: Portugal (nine respondents) and Belgium (eleven respondents).

The non-homogeneous interview participants were from different types of organizations, such as centralised and decentralised manufacturers, fillers, retailers, recycling parks, sectorial federations and academic experts.

During the interview's general aspects of the observed behaviours and common practices of the industry were collected and categorised in 5 groups per each organisation type: 1) deign and value creation; 2) process and operation; 3) Key partners and network; 4) craving to innovate; 5) Perception and expectations.

Table 2. Overview of the conducted interviews

Type of organization	State	Interview participant's role	Appendix	Location
Manufacturer (centralized production)	08 October 2019 10 March 2020 13 March 2020	**I1** - Production Manager **I2** - CEO **I3** - Marketing & Product Innov. Manager	Appendix A: Interview Doc. 1;2;3	Marinha Grande, Portugal
Manufacturer (decentralized production)	30 September 2019	**I4** - Technical Manager **I5** - CTO & Innovation Lab. Manager	Appendix B: Interview Doc. 1;2;3	Cascais, Portugal
Goods Producer or Filler	24 July 2019 10 February 2020	**I6** - Senior Strategic Innovation Manager **I7** – Head of Brand for Europe **I8** - Global head of Long-term Innovation **I9** – Incubator Project Lead	Appendix C: Interview Doc. 1;2;3	Brussels, Belgium
Retailer	13 November 2019 15 January 2020	**I10** - Director for Innovation **I11** - Product Innovation Area Manager **I12** – Brand Manager **I13** – Business Transformation Manager	Appendix D: Interview Doc. 1;2;3	Oporto, Portugal
Recycling Park	14 August 2019	**I14** - Operations Manager	Appendix E: Interview Doc. 1;2;3	Ghent, Belgium
Industrial Federation	07 November 2019	**I15** - Business Group Leader **I16** - Managing Director **I17** - Manufacturing Manager	Appendix F: Interview Doc. 1;2;3	Brussels, Belgium
Academic Expert	07 November 2019	**I18** – Ass. Professor in 'Circular Plastics' **I19** – Ass. Professor 'Chemical and Mechanical Recycling'	Appendix G: Interview Doc. 1;2;3	Brussels, Belgium
Academic Expert	27 November 2019	**I20** - LCA Researcher	Appendix H: Interview Doc. 1;2;3	Gent, Belgium

Interventions were reduced to a minimum (Guerra, 2006) and the interview structure considered the handling of the physical prototype later in the second half.

The interview manuscripts were transcribed, and the essential message was transferred to the interview synopsis (Appendices A to F). Content and language were kept

true to the interviewees' discourse (Guerra, 2006) and translated into English whenever the interview was conducted in Portuguese.

The *Analytical Grid of the Interview*, describes the issues addressed and its analysis and the *Interview Guide,* describes the interview questions; *Synopsis of the Interviews*, summarises the interviews and is presented below (Table 3).

During the interviews, general aspects of the observed behaviours were collected and included in the next section.

Table 3. Overview of the synopsis of the conducted interviews

Type of organization	**Design and Value Creation** What is the first impression?	**Process and Operations** What are the key transformations?	**Partners and network** What are the key partners or channels?	**Craving to innovate** How does it promote innovation?	**Perception and expectations** What happened afterwards?	**Reflection** How do you think about it afterwards?	**Interwiees**
Manufacturer (centralized production) Portugal	.massive impact on final cost .environment is our priority	.possible to produce with the current machinery and materials	.other flexible need new processes/mach. .users are afraid of spilling chemicals (dislike flexible pack.)	.we need to differentiate, but only with realistic innovation	.we sell less .charge to license per each time the packaging is refilled?	.interesting, changes the geometry but not require significant investment on technology, material, machine or mold	**(I1) (I2) (I3)**
Manufacturer (decentralized production) Portugal	.not interesting (…) reusable packaging goes against our business model	.hole-in-the-wall reduces shipping cost .weight reduction . incorporate PCR PET / HDPE	.work with key actors in the supply chain .incorporate recycled raw materials in customers products	. promote recycling . reduce the consumption of natural resources . help mold consumer's behavior	. implementation of deposit return systems .design and producing reusable packaging .reduce emissions and operational waste	.the shelf is very important, the contact with the end-user .prioritize recycling	**(I4) (I5)**
Filler (production of goods) Belgium	. >3 liters avoid pet competition . >3 liters, the advantage of volume reduction	.identify big consumer problems and look for business and tech. partners	.work closely together along the plastic value chain (collection, transformation, marketing…	. disruptive approach that enables us to accelerate and elevate our R&D processes	.customer valorize environment less than product lower costs	.cooperation between stakeholders is key .work together along the plastic value chain	**(I6) (I7) (I8) (I9)**
Retailer Portugal	.want to reduce the waste at our stores close to zero .working on eco-design, looking for the best solutions	.understanding the client's needs and preferences, followed by a moment of experimentation	.promoting a stronger relationship between producers and academia and research centers	.products made from the surplus of the retail chain (...) made from end-of-life food products from our stores	.reduce, recycle and reuse or packaging its own brand plastic packaging, anticipating 2025 Sustainable Dev Goals	5 strategic pillars: .Energy & Climate Chan. .Circular Economy .Responsible Sourcing .Responsible Offer .Awareness & Education	**(I10) (I11) (I12) (I13)**
Recycling Park Belgium	.package arrive broken, deformed	.all brands are collected together	.unaware of how others (recycle chain) proceed	.no innovation	.just waste .negligible value	.taxation based on weight or volume	**(I15)**
Industrial Federation	.citizens, need to simplification		.it is difficult to motivate the take back	.it could use new materials, with sensors monitoring quality		.companies are very open to circularity, but their focus is economic benefits, not environmental	**(I15) (I16) (I17)**
Academic Expert Belgium		.take-back process also impacts environment	. monetary incentive, as in glass bottles return on supermarkets		. IoT technologies can support the product-service design		**(I18) (I19)**
Academic Expert Belgium		.each case needs an LCA			.need policy development		**(I20)**

4.2.2 Results of the interviews

Three major actions raised from the interviews and are the main required actions to promote the transition from a linear to a circular business model in the plastic packaging industry specifically (and plastics industry in general):

1) to increase collaboration of all value chain to develop waste-free design;

2) to increase communication towards design for long-duration, refill and reuse;

3) to reduce the dependency on fossil resources, introducing recycled resins.

In addition, a simplified life cycle assessment (LCA) emerged from the interviews, especially from the last interview mentioned in Figure 18, the LCA researcher (I20). This interview turned into a series of brief discussions about possible approaches for an LCA.

The extrapolation of the data extracted from the interviews and the researchers' ethnographic analysis, suggested that a detailed LCA should be set aside at this stage. Due to the recognition that the reduction in volume during transport and the prolongation of the circulation time of each package, are advantage known and accepted by all the stakeholders.

However, when the object of analysis is a specific packaging for a specific product and context of use, for a specific transition, an LCA analysis is recommended.

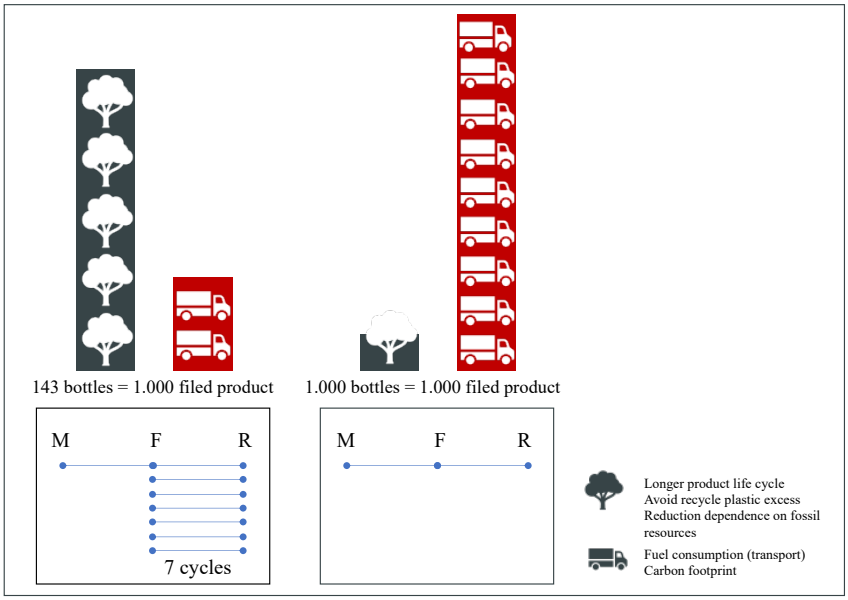


Figure 18. Ethnographic life cycle assessment emerged from the interviews

The relevant information to retain from this exploratory phase of the research is on the one hand, that the ethnographic research conducted used interviews and observation as the preferential interaction means. On the other hand, it may have changed some of the assumptions made by the representatives of the different stakeholders of the value chain.

In order to better exemplify those contradictory assumptions, an additional diagram is presented (Figure 19). The position of the icon indicating the filler (e.g. detergent producer), gives high weight to the “standing-out in the shelf and brand trust” as a relevance to the sales volumes. This assumption is mostly due to the user criteria in the moment of the

purchase, but the end-user or buyer, prints more weight into their decision based on price and waste-free packaging design.

It is interesting to see that the position of the user's perception also favours environmental communication and the brand's popularity, adopting a clear position in favour of cost reduction and waste reduction.

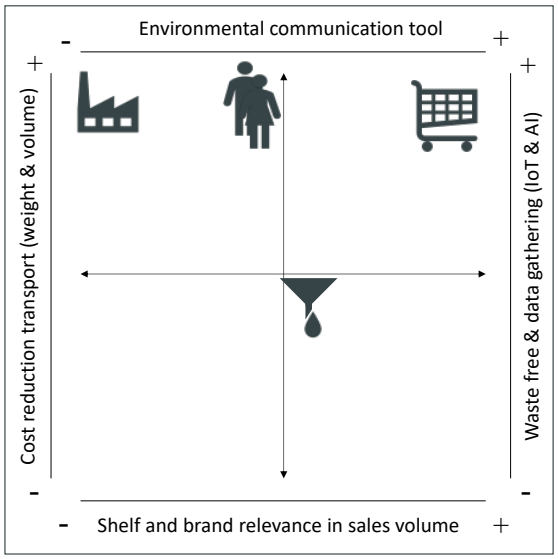


Figure 19. Ethnographic assumptions emerged from the interviews

In turn, in line with the initial assumptions based on the literature review, packaging manufacturers place greater emphasis on reducing transport costs due to the popularity of their brand and environmental marketing. In addition, retailers place greater importance on the brand's popularity, on environmental communication as a sales tool.

This cross-analysis will be addressed further in the chapter 5, namely, during the development of the case study and the description of the scenarios for circular business models. In addition, the analysis of the physical prototype during the interviews, stimulated a deeper understanding. This will also be validating the design requirements and business points of view among the value chain.

Synopsis of chapter 4

Chapter four focuses on the problem statement, introduces the case study and circular business models are discussed.

The chapter starts to describe the principle of WisePack that allows a package to be able to collapse in the pre-filling stage. In other words, it will allow that a package be produced in one place, be folded into a small fraction of its volume and subsequently transported to another site for filling.

Another vector in packaging design, geared towards reducing the volume of waste, concerns its ability to collapse in the post-consumer phase. Although some solutions that contemplate a collapsible function, taking advantage of the structural ribs in the packaging body, even if collapsed, the packaging still occupies a significant part of its initial volume.

In this section the WisePack circular business models' assumptions are described, followed by the stakeholder's interviews and finally, guide the case study analysis developed in the next chapter.

5. DISCUSSION – FROM PRODUCT AND SUPPLY CHAIN TO VALUE CHAIN

The general goal of this case study is to understand the various stages of the design process for circularity and to evaluate notation for each process step. These goals are consistent with the analysis process of Bocken (2016) and Kalmykova (2019), considering circular business model innovation and circular value chain, respectively. The case study is based on the reuse of plastic packaging, and design (as a discipline) supports the development of a System-Centred Circular-Design (SCCD) approach.

The current plastic packaging solutions foment the single-use of plastic, in most cases, it design do not facilitate the collecting phase or the self-protection of the packaging, In order to be reuse or refilled after each take-back process. If it is desired to maintain the minimum configuration on current packaging solutions, it is necessary to use a cover to create a vacuum inside the package. This contradicts the recommendations of recyclers who request to remove the air collapsing the packaging and put the cap back on, to reduce the volume. This is possible because the 2 different materials will easily separate by their density in water after shredded.

The WisePack was chosen to the analyse and reverse of the design process due to be a packaging that promotes a reuse and refill business models due to its geometry, if the analysis verify the assumption, the research findings will answer to the stablished question: “How can design be a source of innovation to transform businesses models accordingly to circular economy principles?”.

CASE STUDY GOALS

The goals addressed in this research entail learning about SCCD.

GOAL 1: Learning about SCCD. The following secondary goals are intended to understand better the possible advantages associated with the adoption of the circular design framework. The lessons learned from this study regarding these secondary goals are discussed in chapter 6.

Secondary goal 1: Identify potential benefits and archetypes of the circular product value chain.

Secondary goal 2: Investigate suitable value chain typologies, as perceived from the results of ethnographic analyses of the interviews (Chapter 4).

Secondary goal 3: Analyse the business model innovation strategies. Identify value flows and primary sources of revenue.

Secondary goal 4: Recommendations to develop a SCCD process for innovation.

GOAL 2: Evaluation of the SCCD guidelines. The SCCD is presented as guidelines that support the creation, analysis and execution of specifications and formal process designs. As such, it needs to be able to represent specifications and process designs in a complete and concise manner. The creation of SCCD approach requires characteristics of value proposition, value creation and value retention, modularity and several circular-design archetypes to extend the product's life cycle.

In order to evaluate the generated business model's simulation, schematic representations were performed where it contained the characteristics necessary to satisfy the claims made by the system of the analysis. Lessons learned are presented in Chapter 6, as well as the analysis and execution required to perform dynamic analysis and simulated execution – the future scenarios that could prevent the single-use of plastic packaging.

A System-Centred Circular-Design (SCCD), by its systematic nature, provides several concepts for building new and more complex collaborations in the supply chain. This relationship in the circular process is defined in terms of attributes. The attributes, geometric characteristics and functions are used to facilitate the instrumentation of this innovative process. All these notation characterisations of SCCD appear to be viable for the process specification and design phase. It supports refinement and abstraction, making the SCCD framework easy to understand and use. Figure 20 represents the data flow diagram used to build the case study.

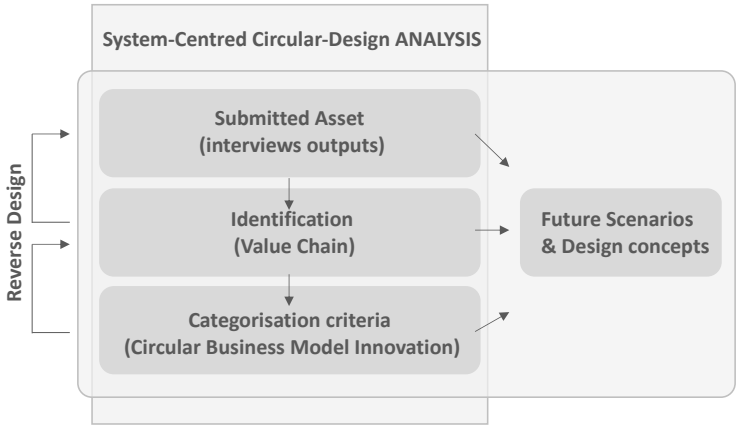


Figure 20. SCCD analysis data flow diagram

Like other innovation processes, the degree of uncertainty associated with implementing a new design approach is too high for companies. Companies are set and established in their traditional way of operating but feel impelled to react, adapt and try to explore different ways of operating. These different methods involve of measuring intangible and long-term design solutions, which allow a transition to circular business models. This chapter will also discuss the role of design in embracing innovation in this transition to a circular economy.

5.1 From linear to circular design – Product-as-a-Service

A key strategy to create a circular economy is based on providing services instead of, or in combination with, selling products. Currently, a product-as-a-service model is a value proposition in which a combination of product and service elements is offered to the customer and can be used to enable circular value creation.

People use this model everywhere in the globe. For example, a library or the electricity bill, provides the service without user ownership obligations. In the last decade, however, the technological advances made it possible for new business. Companies like Spotify added the value of listening to music to its customers, without ever having to produce, distribute and use a CD. The owner of the products is the company and that allows them to engage in partnerships with key partners in its business model.

Designers are now challenged to include in their development process, information such as product disassembly attributes or the bill of material specifications or organising reverse logistics with potential partners. Value networks can help designers to collect data from these partners to improve the design solution and a SCCD solution.

Primary Raw Material

Figure 21 represents a current linear supply chain applied to the WisePack plastic container, but it also shows a growing number of reasons to approach design process differently and help companies to adjust to a very different future. For example, the access to, and affordability of, mineral raw materials are crucial for the plastics industry (TROCH, 2016), (European Commission, 2016).

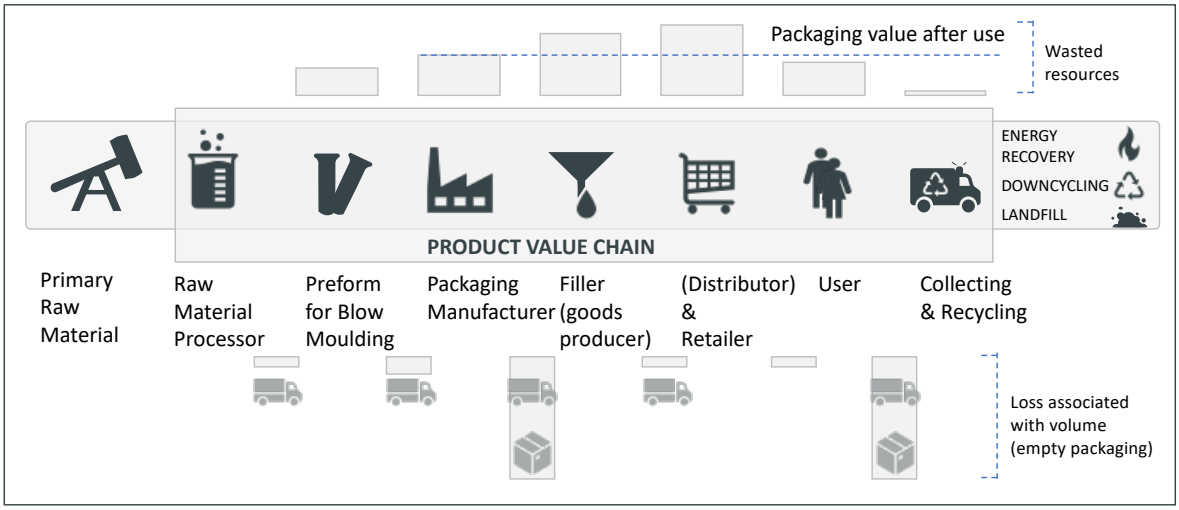


Figure 21. Linear supply chain of the plastic packaging industry

According to the Europe 2020 strategy (TROCH, 2016), many of the emerging trends are related to the adoption of industrial strategies, designed to protect the resource base and generate benefits for its underlying sectors. These strategies are visible through the proliferation of government measures that distort international trade in raw materials (such as export taxes, along with subsidies, price-fixing, dual pricing systems and restrictive investment rules).

Europe dependency rate from energy produced outside the European Union is measured by the share of net imports (imports - exports) in gross inland energy consumption (meaning the sum of energy produced and net imports). In the EU in 2018, the dependency rate was equal to 58 %. This means that more than half of the EU's energy needs were met by net imports. The EU mainly depends on Russia for imports of crude oil, natural gas and solid fuels, followed by Norway for crude oil and natural gas (European Commission, 2018a).

In the field of nanotechnology, for example, researchers are looking to self-healing materials, those materials are developed to heal themselves when thermal or mechanical damage occurs. These full or partial recoveries of its mechanical strength open broad possibilities to designers. WisePack's collapsibility ability could be self-healing in the critical foldable areas, and that should extend its number of reuse cycles and consequently the product life-cycle. Moreover, the usual types of self-healing materials are based on polymers that heal their broken bonds. Researchers have developed both self-healing rubber

and self-healing glass. These new material studies have grown remarkably, and nanomaterials can have a huge impact on the plastics industry.

These transformations are changing the supply chains. Often, the supply chain is too simplified on basic models, as is shown in Figure 21, but in reality are complex, non-linear, multidirectional and interconnected (Coursera, 2020). The European Green Deal (European Commission, 2018a) takes supply chains to the next level of complexity, but that makes them challenging to trace and this makes it hard to see exactly who is part of it and how they function (Coursera, 2020).

Designers need to adapt to goals on the European Green Deal. It aims for climate neutrality by 2050 and includes (European Commission, 2018a): zero pollution; affordable and secure energy; smarter transport and high-quality food. It provides a roadmap with actions that are relevant to the product value chain and its supply chain:

- to enhance the efficient use of resources by moving to a clean, circular economy;
- to restore biodiversity and reduce pollution.

To complement the factors already mentioned earlier in this section:

- reliable access to raw material;
- reduce the European dependency rate from energy produced outside the European Union;
- government directives to transition to a circular economy (European Commission, 2018a);

There are other factors that are driving this transition from a linear to a circular economy:

- new technologies admit new manufacturing processes and disruptive business models;
- the environmental impacts, energy consumption and waste reduction;
- the consumption patterns and the conscious and participative user.

Over the last decades, the focus has been in the effort to reduce material losses and bring materials back into new material loops. As mentioned in chapter 2, Europe has been prosperous in recovering materials from industrial residues and reintegrating them in the

production process, and at the end of the product life, bringing materials back into the loop through for example waste collection systems and treatment facilities. However, as discussed in introduction and chapter 2, recycling and waste management is insufficient to reach those goals. The development of tangent cycles is required in the design of a circular product in order to manage the products and the material in a different way and evolve in the direction of dematerialization.

The conventional cycles refer to dismantling end-of-life products and sort them into single materials, which are used as raw materials for new products. The inner cycles refer to different strategies to retain value by extending the lifetime of the actual product and only after their longer cycle in the economy, they return to their material basic-functions.

These endurance cycles are shorter than the conventional loops and are achieved through repair, reuse and remanufacturing design strategies (Figure 22).

Design for refurbishing or remanufacturing strategies also set up shorter loops, allowing designers to create a loop back to the production stage, keeping the value and functionality of the products in circular savings for longer.

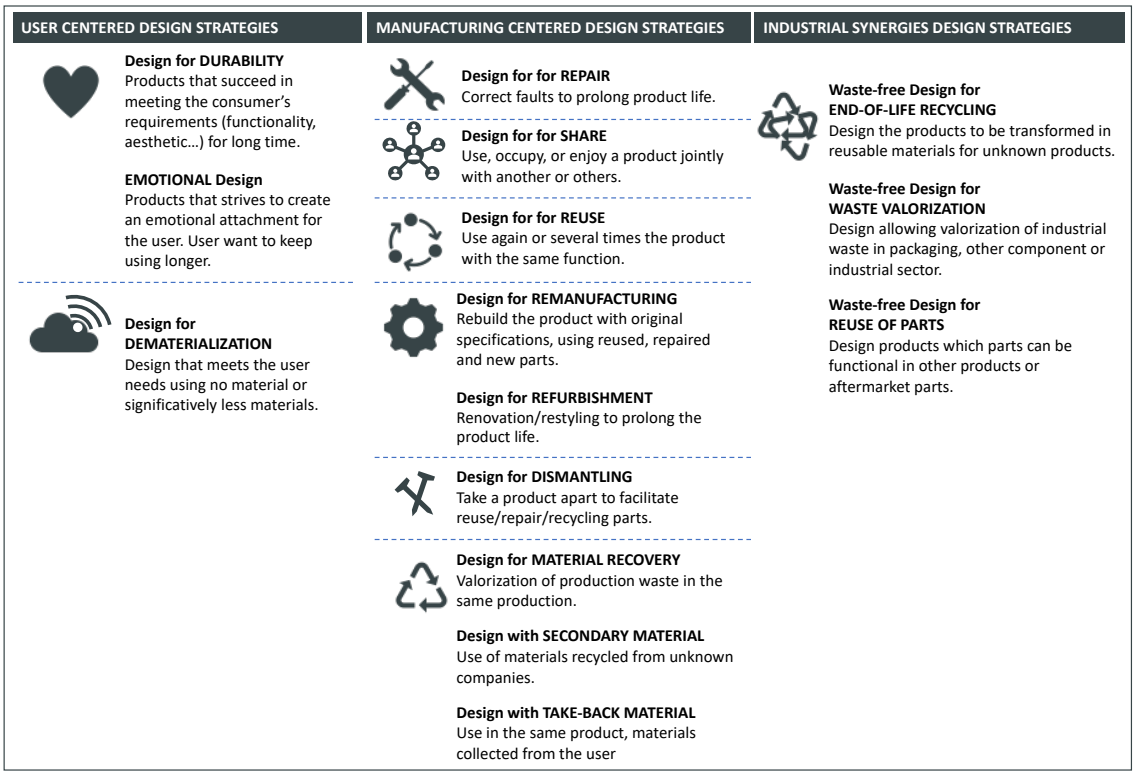


Figure 22. Design strategies to increase product circularity

In Figure 23, the relation between the several cycles is represented and based on this scheme, several circular business model archetypes can be explored as bringing forward a design solution. Short loops as in the design for repair strategy can quickly return to the use phase. Slightly longer loops such as in the design for repair strategy can extend product lifetime, and the long loop either retains value in the loop for longer through the durability of the design solution (which is presumed as a basic request of circularity) or by design for reuse strategy where the same product goes back to other stakeholders of the value chain several times during its life-cycle.

For example, a washing machine can be designed to be repaired or lent to optimise its life while in the "use" stage of the value chain. A plastic or aluminium water-bottle which is refilled by the user is also a strategy to prolong the use of the product. However, if the user goes to the retailer to fill the water bottle, this represents a new loop. Reuse loops are often avoided due to the complexity of partners' management and logistics, but with the digitalization of industry, that complexity can be overcome.

As exposed in chapter 2, the decentralisation of the production demands high investment from the manufacturer due to the need to install production lines (hole-in-the-wall) in each of their customers (fillers). This manufacturing model is likely to continue operational, and the industry digitalization will also be supporting it. Nevertheless, digitalization offers new opportunities to companies with less capability to make such investments and allow SME's to compete with big players in a global market.

The designers that adjust their design solutions to these opportunities can promote innovation and support the companies' transition from the linear to a circular economy.

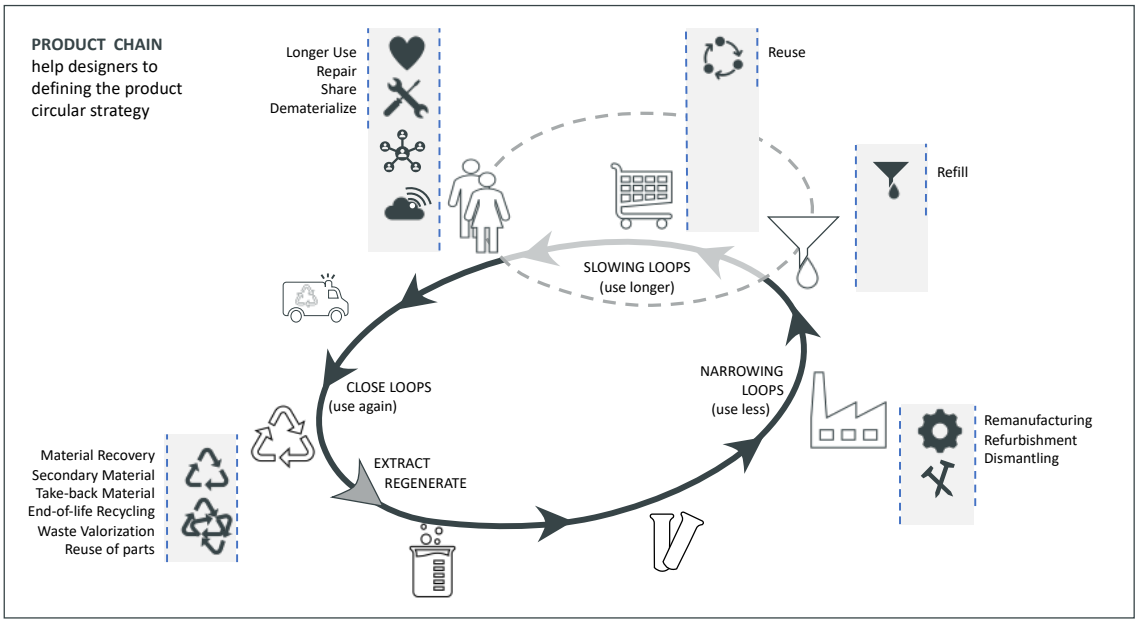


Figure 23. Circular product chain: circular business models archetypes

Figure 23 represents the archetypes of circular business models applied to the study of the WisePack solution. The product chain can be useful to support designers in the definition of the product circular-strategy. Once defined, an assessment will be made as to whether innovative business opportunities exist, and if through Design, competitive advantages can be generated according to a circular perspective.

In a supply chain, the flow of materials and, consequently, cost and revenue flux will be evaluated (purchase and sale). In the circular economy, it is also important to assess transfers of value from one segment to the next. This decision process on the part of the designer is usually called the design thinking of mapping.

The mapping of actors and links between processes or transformational segments does not guarantee all the potential results of the business plan. However, it is a decision process that can create the right arguments to support the implementation of an innovative design concept.

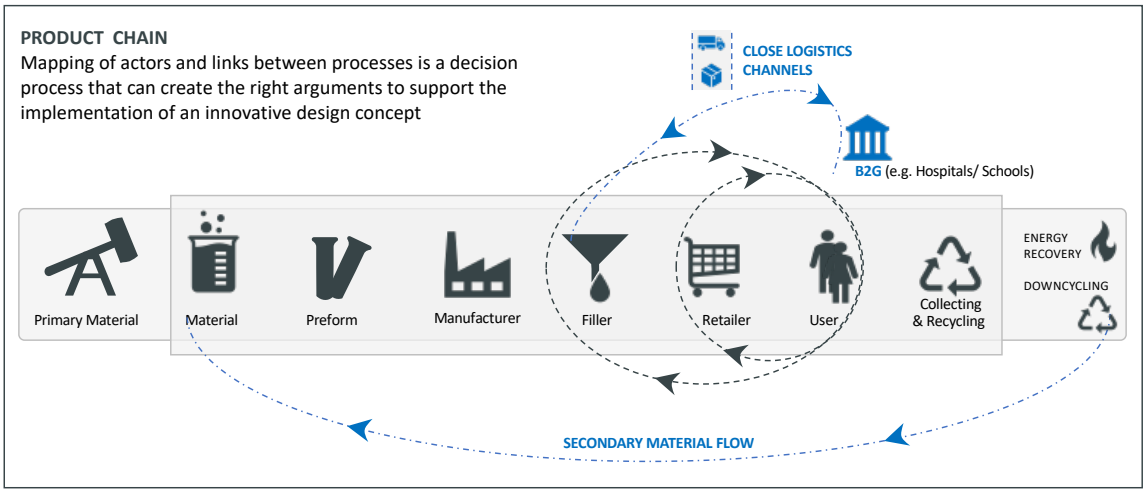


Figure 24. Mapping of stakeholders and links between transformational processes

The important observation resulting from these analyses is that any visible value in the form of materials, commercialized services, monetary exchanges or key partners/suppliers, results in commercial transactions. These transactions are not always monetary, and a design solution must be able to project accordingly to this ecosystem approach. For example, one partner has a competitive advantage over the other due to the conditions or characteristics of the transaction. The objectives of these transactions allow the designer to find design attributes, specifications that respond based on the materials that flow between segments of a value chain, and what needs these transactions are intended to meet.

Furthermore, these types of responses require a more detailed analysis of value transactions which are tangible and intangible and potentially extend a product design solution to a product-service solution. The next section of this chapter aims to explore these value transitions and as a result, circular business-model innovation is expected to emerge from the establishment of scenarios.

5.2 Circular business-model innovation

To better introduce the next phase of the SCCD analyses, it is important to address the meaning of innovating the business model. In the context of this study, innovation happens when it alters or relinks some of the business model elements.

The research question of this study is “How can design be a source of innovation to transform businesses models accordingly to circular economy principles?”, so the main focus is if these scenarios show that changes or relinking with a circular-design strategy in

mind, and the shaping and adjusting of these elements provide the guidelines for design in a circular economy context. Chapter 6 explores some implementation of the main strategy and identifies how to overcome barriers to capture value.

There are certain elements that can be adjusted to capture value in a circular business model. This adjustment can generate revenue from selling the same product several times or from capitalizing on the environmental benefits associated with resource conservation. There is also potential to reduce production costs by maintaining the product circulating inside the value chain and it after all as secondary materials or by avoiding costs for end-of-life disposal.

When a design solution innovates on a business model level, it can align the core value creation logic of a company with a circular strategy in a more systematic way. For every design solution, depending on the business model and on the circular strategies planned, it will generate several competitive advantages and products/ service differentiation. Any design solutions will be shaped differently.

Such transformations request attention as to how these data are shaped and designers should make sure that their project supports the implementation of the circular strategy, in a way that circularity becomes part of a company's value creation logic and the barriers can be gradually removed.

The scenarios presented in the next sections are based on the canvas developed by Julia Nußholz (Nußholz, 2017) and through designing circular business models, it is possible to see specific changes in the transition from moving away from linear patterns by slowing and closing resource loops.

As argued in the previous section of this chapter, to implement and capitalize on circular strategies, business model innovation appears to be an important enabler. Furthermore, the mindset focus on circular approaches since the beginning of the design process, seems to be more efficient due to constraints of an ecosystem approach which help to identify transitions that "create, deliver, and capture value".

Business models describe the elements of a company's value creation architecture that define how an organisation converts resources and capabilities into economic value (Nußholz, 2017).

The business model canvas used for this analysis was conceptualized according to Osterwalder and Pigneur's (2010) framework.

Table 4. Value dimensions and business model elements.

VALUE CREATED	BUSINESS MODEL ELEMENTS
VALUE PROPOSITION “What value is required and to whom?”	• Design offer; • Unique selling proposition; • Market segment; • Stakeholders / partners relationship
VALUE CREATION “How is value created and delivered?”	• Key activities • Key resources / capabilities • Key partners • Key channels
VALUE RETAIN “How is value captured?”	• Costs • Revenue flows

Adapted from (Coursera, 2020)

The authors distinguish nine business model elements that describe three value dimensions that will be used in the analysis (Table 4):

1. Value Proposition dimension, aims answer the question "What value is needed and who is it for?". This dimension addresses the elements that may stimulate innovation on a business model, such as design requirements; single sale proposal; market segmentation and the nature of the relationships between stakeholders and business partners across the value chain;
2. Value Creation dimension, aims answer the question "How is the value created and delivered?". This dimension is an effort to identify the key factors generating the circularity ether it is in the definition of a new business or in the transition from a linear to a circular business model. From de clear definition of the several possibilities of approach (circular scenarios), different key activities emerge, and consequently, key resources, capabilities partners and channels start to be delimitated. With these requirements also emerge constraints to the design and to the business itself. This complex and systemic data collection supports managers to:
    a. make their decisions based on design strategies tailored to your needs and budget;
    b. introduce zero waste solutions to the market;
    c. place effective circular systems, which adopting digitalization and new technologies

3. Value Retention Dimension, aims to answer questions such as “How is value captured and retained?”, “How are circular products priced?”. This dimension deals with the flows of costs and revenues. Qualitative comparisons between the linear and circular approaches, the results of which depended on:

d. type of private information the customer has:
    i. any horizontal uncertainty regarding brand preference;
    ii. vertical uncertainty in relation to quality preference;
e. competition increases, the resulting quality distortions decrease, as well as price and quality dispersions.

Those are the dimensions use in the analysis shown below.

5.2.1 Scenario 1: Circular Business Model Analysis

Company case: Description

In scenario 1 the resources are maintained in the value chain through a circular flow of material and functionality. Scenario 1 focuses on developing better systems that optimise the use of resources, maximizes the total life-cycle -value of the packaging and minimizes the cost of ownership for the customer (filler). Looking at the package through a total life-cycle perspective, and working in partnership with the filler and distributors, allows the company to make sustainable progress and also minimize the cost to the final user. The public-organisations such as hospitals or schools and the HoReCa-firms such as hotels or restaurants are targeted as final users, and due to the fact that their distribution channels are often simplified, it skips the retailing point. Operating directly from the filler to the user demands minimum changes on the operations and take-back management. This, reduces the resistance to change, facilitating the implementation of the innovative process.

5.2.1.1 Scenario 1 Phase 1: First-Sale Cycle

i. VALUE PROPOSITION

In the first-sale cycle, the *offer* is the packages and the services. The company licenses monitoring services and the respective equipment to their customers (e.g. removable chips, code or colour indicator and chips reader technology) and performance digital monitoring of the number of the cycles performed by each package. The chip also indicates the level of stress that the material was exposed to, depending on the products that it contained in the previous cycles (e.g. hospital chemicals may offer higher stress on the material).

As a *value proposition*, the company provides customers (fillers) with quality packaging that provides the best economic offer and lowest life cycle costs for their business, including collapsible geometry for increasing efficiency in storage and transportation before filling (first-sale cycle) and after use (collect & refill cycle) throughout the life of their packaging.

The company operates through its two main segments. The suppliers of:

- Public organisations (hospitals, schools);
- HoReCa-firms (hotels; restaurants).

A close *relationship* with the customer is important due to the adaptation of his production line and the collaborative work on the sales channels (targeting for a second sale of the same product).

ii. VALUE CREATION AND DELIVERY

Manufacturing, and establishing the sales channels are *key activities,* while *key resources and capabilities* are the companies' manufacturing technology (mould and blowing technologies) as well as the packaging design for refill and reuse.

The *key partners* are the moulds manufacturers, logistics and transportation partners. The sales channels need to develop a strict partnership with the customer and the transportation *channels* are also specific to these products.

iii. VALUE CAPTURE

Moulds *costs* make up the largest share of production and operations costs, followed by fixed costs such as labour. *Revenue* is generated through the sale of packages

and monitoring services (software IP licensing is an option for the customer - in house monitoring).

5.2.1.2 Scenario 1 Phase 2: Take-Back Cycle & Refill

Refills using a used package, labelled as reusable, and with a price well below the price of a new one. Through offering refilled packages, the company can tap into the after-market of their products and expand to customer segments to whom the lower price is attractive (e.g. restaurants and hotels).

i. VALUE PROPOSITION

To organise take-back and refill the packages in the value chain at the end of their first-use cycle, the company collaborates with the customers (fillers) to integrate the shipping return, into the delivery on the refilled products distribution channel. Due to the collapsible characteristic of the packaging, it avoids contamination and the storage area is reduced up to 10% when compared with the filled packages.

A financial reward as a cost reduction upon the packaging return is simultaneously an incentive and an *offer* to the customer.

As *value proposition*, customers have: a reduction on the cost per package on each exchange, decreasing accordingly to the number of cycles; a reduction on storage and transportation costs due to optimisation on volume; minimum contamination resulting in water and washing cycles costs; and a combined take-back and delivery system.

Increasing the recovery rates is a challenge for any manufacturer engaging in reintegration of the plastic in the production of new packaging. Nowadays, the integration of recycled material is basically the waste of production and rejected products. Some companies buy recycled material from raw material suppliers, thereby closing the loop.

ii. VALUE CREATION AND DELIVERY

Motivating the returns in specialized containers that only allow collapsible packaging is the *key activity*, while the others which involve collecting the used packages include reverse logistics and monitoring services. Other *key resources and capabilities* are the reverse logistic network and transport capabilities, as well as a close relation with the customer network to facilitate several take-back cycles. Software and chips technologies are also additional resources.

Operating reverse logistics, as well as share transportation costs, are substantial *costs*. Still, additional *revenue* is generated by additional sales of the same product and by retaining value in its own value chain.

The main *channels* are the distributions partners. It is common that public organisations and HoReCa firms have their contract with periodic deliveries (in closed loops) in order to get better price due to economy of scales. This distribution partner also does the collecting of the packages and because of the collapsibility of the packaging, when closed, remains clean and free from internal contamination, as well as its surroundings. This is not possible in the recycling containers used nowadays.

Key resources and capabilities are those that operate *key activities* such as use-cycles counting, quality checks and reverse logistics.

Key partners include partners developing quality monitorization, testing technologies and distributions technologies.

iii. VALUE CAPTURE

Costs include logistics, quality monitorization and testing (technology and labour), but through additional sales of the product and the attached services, the company continues to generate revenues and makes the most out of the value embodied in the same product.

5.2.1.3 Scenario 1 Phase 3: Additional-Sale Cycle

OFFER and VALUE PROPOSITION

The company engages itself in a circular value creation. Their strategy focuses on the relationship with the customers (from product to service), providing a service that addresses the needs of their customer as if it were a sharing platform. The package is reclaimed and refilled, then resold in a "sale as new" condition to a market that valorises lower prices. This enables the prolonged use of the package and allows an additional cycle of sales for the company – slowing the loop.

A service-oriented strategy is put in place, as well as the monitorization of the number of cycles of use per package. The strategy in this scenario allows the company to keep embodied value within its own network, with the advantage of offering the monitoring services or IP licensing, thereby increasing the value per package with several use cycles.

Summing up, the customers/partners relationship is closed and is service-oriented. The collaborative work in reverse logistics and refill-technologies (design, chips and

moulds) between the stakeholders using the sales and distribution channels, results in several additional sales and monitoring services, as revenue flows. This will offset the extra operational and reverse management costs.

5.2.1.4 Scenario 1 Phase 4: Enable Material Recovery

In order to enable material recovery, the material must be single-layer (mono-material), the chip, labels and caps must be easily dismantled or disassembled. To motivate the return, a close relationship with the distributers is required and an additional collection scheme and management procedures are required. The key cost is related to transport and the return is on the material recovery.

5.2.1.5 Scenario 1 Phase 5: Collect & Reintegrate

REDUCE PRIMARY MATERIALS

The reduction of primary material is acquired with the incorporation of recycled material. This is a process in common use by the plastics industry. Nevertheless, the volume of secondary material grows with the take-back process and the complexity of the material processing increases, since the separation, washing and shredding are done in-house in order to retain embodied value.

The *key activities* are the storage and processing of recovered material. The folding of the packaging avoids contamination and the specialized collecting container simplifies the separation process. If a package does not collapse, it cannot be collected by specialized containers and a pre-selection is already made at the user's level.

The key resources and capabilities are related to the returned material which must be separated, cleaned and granulated to be processed and reintegrated.

By processing it in-house, *key partners* and *channels* are not necessary.

Labour *costs* are the most significant of the overall cost, but the closing resources flow generates *revenues* due to the reducing of primary material, capturing value from maintaining and utilizing the embedded value in resources for as long as possible.

Table 5. Circular business model – scenario 1: Refill

(Based on (Nußholz, 2017)(Mont et al., 2017) Additional readings (Nußholz, 2018)(Nußholz et al., 2019))	First sale cycle (with prolonged use)	Collect & reintegrate (organise take-back)	Additional sale (organise refill)	Enable material recovery	Collect & reintegrate (reduce primary materials)
VALUE PROPOSITION					
Offer	Package & services	Financial reward upon return	Resale	Material recovery (body)	Incorporate recycled material
Value proposition	Quality & collapsible package; Low Life Cycle Cost; monitoring	Minimum contamination or damage; Reduce storage area; Combined take-back and delivery;	Cost reduction per cycle; ; Low Life Cycle Cost	Totally recyclable; Easy disassembling (chip, label and cap)	Reduce primary material
Customer segments	Public Org. and HoReCa suppliers	All Public Org. and HoReCa suppliers	Public Org. and HoReCa suppliers	-	Own productions
Relationships nature	Close relationship and co-creation with the fillers; Service-oriented relation	Collaboration with distributors; Service-oriented relationship	Close relationship with the fillers; Service-oriented relationship	Collaboration with distributors	-
VALUE CREATION & NETWORK					
Key activities	Manufacturing; Establish sales channels	Motivating return; Collect; Reverse logistics and monitoring	Collaborative-work management	Motivating return; Collaborative work management	Process secondary materials
Key resources/ capabilities	Design for refill & reuse; Manufacturing technology; Moulds design	Collection scheme and management; Reverse logistics & transportation	Design for refill; Collapsible geometry;	Collection scheme and management;	Processing material to recycling (wash & shredder)
Key partners	Moulds manufacturers;	Chips and readers manufacturers	Costumer (to resale); logistic and transportation partners	-	Transportation
Channels	Sales, distribution & transport	Transportation channels	Transportation channels	-	Transportation channels
VALUE CAPTURE					
Costs	Moulds; Production and operations; Labour	Reverse logistics management; transportation costs	Operations & management; Remote labour for control checks-services; Chips reading equipment	Transportation	Labour & process
Revenue flows	Sales; monitoring services	Quality checks services & licensing of monitoring equipment	Additional sales; monitoring services	Material recovery	Reduce primary material

Table 6. Circular business model - scenario 2: reuse

(Based on (Nußholz, 2017)(Mont et al., 2017) Additional readings (Nußholz, 2018)(Nußholz et al., 2019))	First sale cycle (with prolonged use)	Collect & reintegrate (organise take-back)	Additional sale (organise refill)	Enable material recovery	Collect & reintegrate (reduce primary materials)
VALUE PROPOSITION					
Offer	Package	-	Resale; fraction of the packaging cost (more margin & flexibility promotions)	Material recovery (body); Less volume to collect, storage and transport	Financial reward upon return; Incorporate recycled material
Value proposition	Quality & collapsible package; Low Life Cycle Cost	Reduce waste in store; Open to user participation (user-fidelity for the retailer)	Cost reduction per cycle; Low Life Cycle Cost	Totally recyclable;	Reduce primary material
Customer segments	Hypermarkets & retail stores	Users (similar to supermarket bags)	Users (similar to supermarket bags)	-	Active end-user
Relationships nature	Close relationship	Close relationship	Close relationship	Close relationship	Community-based, transactional
VALUE CREATION &NETWORK					
Key activities	Manufacturing; Stablish sales channels	Collaborative work	Collaborative-work management (including fillers)	Motivating return; Collaborative work management	Motivating return and online register
Key resources/ capabilities	Design for refill & reuse; Manufacturing technology; Moulds design	Partnership establishment (retailers & fillers)	Design for refill & collapsible In-store dispenser; Large containers (filler)	Collection scheme and management;	Collecting scheme; Online platform costumer area
Key partners	Sales; Retailers	Retailers & fillers	Costumer (retailers); Filler (containers)	-	Take-back organisation & transport
Channels	Retailers	Retailers	Retailers	-	Discount or free shipping for registered users (volume class)
VALUE CAPTURE					
Costs	Moulds; Production and operations; Labour	-	Operations & management;	Transportation	Labour & process
Revenue flows	Sales	-	-	Material recovery	Reduce primary material

5.2.2 Scenario 2: Circular Business Model Analysis

Company case: Description

Products such as multi-components products, often use modular platforms and their circular business models can be designed for dismantling and reuse. For example, the manufacturers can directly cooperate with its customers by offering a discount on new products when an old one is sent back. The manufacturer can then re-market the collected

product in other markets or can capture residual material value by sending the product to a recycler.

To extend the life cycle of a plastic bottle, a label and a cap can be updated but the core must be reused for several cycles. By facing a user who is more aware of the environmental consequences of the consumerist and more participatory world, the requirements for manufacturers are higher and the companies feel the need to offer different solutions where the users are more active and participate as important stakeholders of the value chain.

This challenge also creates an opportunity for packaging manufacturers who can explore their relationship with the end user. By knowing their users, they can better encourage return cycles, request feedback and better understand their needs.

This also allows manufacturers to be less vulnerable to price reduction pressures from consumer goods companies (e.g. home and household producers), on the one hand, and oil price fluctuations, on the other - reducing the dependence on oil dedicated resources by reintroducing recycled material into new products.

In scenario 2 the resources are also maintained in the value chain through a circular flow of material and functionality. Nevertheless, scenario 2 focuses on the relationship with the end users. The company engages itself in a circular value creation, from product to service, providing a service that addresses the needs of their customer, working in strict collaboration with the fillers and the retailers, which position themselves as suppliers on a non-package platform.

The packaging is sold to the customer and the customer fills it in with the specific environmentally friendly brands that the filler provides in large containers (e.g. 200 litres). The retailer needs to change their infrastructure to install dispenser taps in their shopping area. By leaving the shelves for the premium brands, this reduces waste and labour in the retail store.

Principally, a better system is developed that optimises the use of resources, maximizes the total life-cycle -value of the packaging and minimizes the cost of ownership for the filler. The take-back management is facilitated due to the reduction of volume in storage and transport offered by the collapsible geometry of the package.

5.2.2.1 Scenario Phase 1: First-Sale Cycle

i. VALUE PROPOSITION

During the first sale cycle, scenario 2 is similar to the previous one. As *value proposition*, the company provides the best economic offer and the lowest life cycle costs for their business. The collapsible geometry of the package increases efficiency in storage and transportation before and after filling, but in this scenario the user reuses the package several times and refills it at the retail store. This is similar to what happens now (with plastic or paper bags), although it has extended sales to liquid products.

The *customer segments* are no-package areas of hyper- and supermarkets (retail stores).

A close *relationship* with the customer (retail stores) is important due to the adaptation of the store infrastructure, namely the distribution dispenser and the storage of the large containers in the warehouse. The relationship with the consumer goods company is also close.

ii. VALUE CREATION AND DELIVERY

The *key activities* and *key resources/ capabilities* are the communication and management of the collaborative work with the key partners: the customer (retail stores); the consumer goods companies.

iii. VALUE CAPTURE

The moulds *costs* are the largest share of production and operations costs, followed by fixed costs such as labour. *Revenue* is generated through regular sales.

5.2.2.2 Scenario 2 Phase 2 & 3: Take-Back; Refill and Additional-Sale Cycles

The take-back phase is highly simplified when compared with scenario 1 and very similar to a traditional linear business model. In the additional sale cycle the advantages are mostly for the retail stores and consumer goods companies, but that is a strong argument for them to engage in this scenario concept and shift to a circular business model.

The Key activities; resources and capabilities are mostly collaborative-work management and user engagement.

Innovating business models can assume two forms. It can result in an entirely new business model or, in the reconfiguration of the elements of an existing business model.

Business model innovation can aid to devise an offer and a value proposition that proactively embeds a circular strategy to prolong the useful life of products and parts or closed material loops. By rethinking the three value dimensions, business model innovation provides a more holistic approach for aligning the value creation logic of the company with circular principles (Coursera, 2020).

To preserve and utilize the embedded value in WisePack packaging, and materials for as long as possible, the business model needs to change their focus beyond a single-use cycle (linear approach) by enabling interventions as several use cycles and end-of-life recovery.

WisePack's new generations of packaging, need to be devised with the respective circular strategies and interventions in mind and adjusted to support its implementation. In the next chapter some of these new generations of packaging will be explored, based on the results of the case study analysis - the SCCD.

To summarize, the circular business model analyses guide designers to identify which interventions need to be considered to design circular business models. It also supports designer's communication with the companies to navigate innovative options and radically different approaches to their business model. It helps to plan and analyse the business model elements for each design solution so that it can be implemented, in order to consolidate circular strategies and map the interdependencies of business model elements across the life-cycle.

Additionally, it can help to identify opportunities to capture the residual value of products, parts and materials and reduce the related environmental impact.

Synopsis of chapter 5

Chapter five is dedicated to the design guidelines. Recommendations for circularity are generated with the methodological tools as well as the product and value chain analysis, and value creation scenarios are generated.

The Wisepack case-study outlines the most important issues that need to be considered in selecting these design strategies and define the circular business models in an early stage of product and service design. The qualitative nature of the research and aims to raise information from different angles to understand the constraints and objectives among different stakeholders of the value chain.

6. A FRAMEWORK: RESEARCHING AND DESIGNING CIRCULAR SYSTEMS

The implementation of the scenarios explored in the previous chapter is dependent on the existence of companies available to transform their business models considerably. To initiate the process, it would be advisable for manufacturers to formalise several strategic partnerships and diversify the existing supply chain.

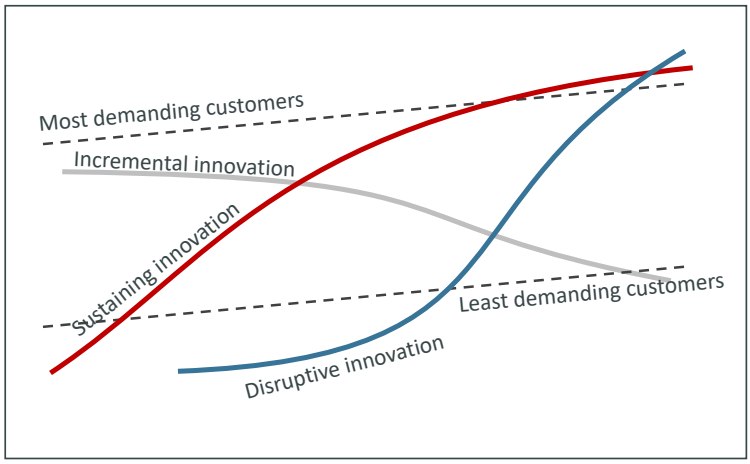
Independently of the stakeholder activity with whom the manufacturer establishes the partnership, the nature of the partnership can profoundly influence the design strategy (and vice-versa).

The research question of this research aims to understand if the design can be a source of innovation, evaluating the nature of the key partnerships recommended as an outcome of the analysis and reflecting on how circular design recommendations can encourage innovation. The next section presents a reflection around innovation in order to understand better how the nature of those partnerships can create constraints to the design processes; and how design strategy can influence innovation processes.

6.1 Four circular design recommendations (CDR) to encourage innovation

How can design become a source of innovation and support manufacturers to create differentiation, developing uniqueness of its business and guide this transition for circular approach? What is proposed in the previous section is that first- and second-line suppliers compete with industry giants on their own market.

According to professor Clayton Christensen, from Harvard Business School, (Christensen et al., 2017) the strategy to follow is the disruptive innovation. Companies can become more competitive with disruptive innovations that either create opportunities in new markets or take over the worst customers from a well-established player. Christensen (Clayton M. Christensen et al., 2003) research overwhelmingly suggests that companies should seek outgrowth based on disruption.



Source: adapted from (Kylliäinen, 2019)

Figure 25. Seeking growth based on disruption

Big market players (fillers or consumer goods companies) mostly focus on sustaining innovation. Their existing products and services are upgraded to attract high profit consumers, neglecting all the regular consumers who just want convenience or simplicity and low-cost alternatives. Sustaining and incremental innovations are often practiced because they are most profitable, and the risks involved are lower.

CDR 1: Implement disruptive innovation

Large companies stay focused on more profitable customers and over-serve adding marketing arguments and features that push the market and not necessarily ensure a need from the user (scenario recycling Table 1). The disruptive design improves the products and services to answer to the requirements of more stockholders. According to Christensen (Christensen et al., 2017) disruptive innovation takes a share of the market and make the consumer goods companies react by launching their own disruptive innovation (e.g. Crest White Strips from P&G which is a cheap, DIY alternative to an expensive dental service).

CDR2: Develop new value networks: participative user and change social behaviour

In the linear economy, sustaining innovation, instead of creating new value networks, improves and extends existing ones, satisfying the needs of users, or generating needs for the user. The designers, at the beginning of the design process, ask "What is the end-user's need?".

Design performance of sustaining innovation create value on existing products, narrowing loops, which is typically what currently companies are doing: reducing the amount of materials needed per product or service; resource efficiency; or doing more with less; which is also an opportunity to save costs.

In the circular economy, disruptive innovation, designers must ask "How can the user be engaged and encouraged to participate in the process (of the product life cycle)?". This change in approach to the design process can cause a change, is based on user behaviour and demands active stakeholders in the circular business model.

Design for circular economy takes into account what happens with the product after it has been used and before it goes for recycling (closing the loop). “Can the product be reused or remanufactured?” – The answer to this question depends immensely on the user's willingness and availability to participate as an active actor in the value chain. Although the current design recommendation refers to the creation of value networks at several levels of the product chain, such as at a technological level (e.g. IoT, big data, AI), logistics, R&D, among others, the user involvement is crucial to, on the one hand, guarantee sales volumes but mainly for slowing and closing loops.

As emerged from the WisePack analysis, in the circular economy, the design effort focuses on retaining the value of products and materials for as long as possible, as opposed to the current linear economy, where many efficiently manufactured products (e.g. plastic packaging) are thrown away after only being used once.

CDR 3: Narrowing loops combining design and innovation strategies.

According to Donald Norman’s definition (Norman & Verganti, 2013) the main ambition of emotional design is to provoke emotions through products and services, improving the user experience. Designers focus on the emotions that can arise from the interaction of a product and he classifies it in three categories: visceral (related with appearances); behavioural (pleasure and effectiveness of use); and reflective (rationalisation and intellectualisation of a product).

Narrowing loops means that designers are requested to develop concepts that change users’ behaviour and are requested to develop products that increase the desire to keep them for longer. Today's emotional design suggestions are extended to induce users to

repair, maintain, upgrade/restyle, refurbish, remanufacture, in order to extend the use-cycle of the products, thereby narrowing loops combining design and innovation strategies.

When using incremental and sustaining innovation strategies, the designed products aim to perform better than the previous generation or competition, for example, by reducing weaknesses, optimising manufacturing processes or transport-optimised stacking, as occurred in the WisePack case study.

Using a disruptive innovation design-strategy, the new product can have improved functionalities and be more profitable than the previous solutions (not necessarily previous generations of the same product) or it targets more high-profit customers. However, it might lead to lower volumes and thus higher absolute profits. Design can make that happen if it uses a system approach since an early stage in the design process: Planning surrounding services and reuse, remanufacturing loops and created maintenance or data managing services attached to the product itself - design for dematerialization and resource-reduction.

CDR4: Build design concept on volumes and profits arguments

As is the case in the adoption of other innovative processes, it is likely that designers will face some difficulties persuading customers or partners to implement circular and disruptive innovations. It is required to build the design concepts in a way that reduce the uncertainty inherent to any innovation. Arguments such volumes and profits are critical to drive circular design or to attract new partners for a new value chain, when all the stakeholders expect a slow growth, but with a fast profitability.

Any manager of a new and growing company seeks a rapid increase in sales volumes, and designers are sure to be persuaded to make this happen. Nevertheless, it is unlikely that disruptive business achieves growth very fast.

Christensen (2003), defends that well-established markets, design customers (manufacturers and other supply chain actors) are not interested in the strengths of disruptive innovation. Customers resist to innovative design solutions and will mostly focus on the weaknesses, which can drive the circular design to fail. Christensen (2003) points out that keeping the core business of the company growing healthily, will make it easier for the management to wait for the (disruptive) circular business to slowly build commercial mass.

6.1.1 Checkpoint table of the System-Centred Circular Design (SCCD) tool

As result of the case study analysis and the design recommendations, a summary of the SCCD strategies is presented in the Table 7.

Table 7. The three verticals of SCCD approach and key outputs

SCCD CHECKPOINT	OPERATIONAL driven DESIGN strategy		PERFORMANCE driven DESIGN strategy	INNOVATION driven DESIGN strategy
RESOURCES LOOPS How keep the product value longer? How will the user want the product longer?	**Narrowing loops** Less material, resources efficiency, save costs		**Slowing loops** Life extension, reuse, repair remanufacturing, less waste	**Slowing & Closing loops** Dismantling, remanufacturing, recycling & reintegrate materials
STRATEGIC FOCUS Based on (Christensen et al., 2017)	**Incremental innovation** No new value networks, improves existing by satisfying user needs		**Sustaining innovation** Value networks, need new capabilities, moderate risk & grow	**Disruptive innovation** Linear fail, need new capabilities: high risk & huge grow potential
CIRCULAR ARCHETYPES Business focus to develop circular products and transit to a fully circular business model?	**Focus on service** User centred service design	**Focus on product** Product & process design	**Focus on value network** Collaboration with user & companies of the value chain	**Focus on a circular identity** Promote disruptive change in design, manufacturing and use
DESIGN ORIENTATION	**Product oriented** - design for durability; emotional design		**System oriented** - design for repair; remanufacturing; refurbishment; dismantling; recycling	**Ecosystem oriented** - design for dematerialization; share; reuse; industrial synergies
LEADERSHIP NATURE How keep the product value longer? How will the user want the product longer?	**Fertile Fied** Find new users for existing strategic assets		**PacMan** Invest in startups & outsources strategy & R&D to marketplace	**Explorer** Long time labour before profits, progressive solving problems
KEY CAPABILITIES	**Goal oriented**		**Prototype/ project**	**Co-work & open inno.**
KEY CHALLENGES	**Paradoxes & complexity**		**Speed & Ambiguity**	**Risk & Uncertainty**
METRICS	**Return on investment**		**Prototyping and hypothesis**	**Option scenarios**
MARKET: DESIGN MIDSET What does the user want or need? How can we fulfil the user need? What if...? (no constraints)	**As Pipeline Sales** Known market dynamics and business operations (converting leads into customers for the product or service design)		**As Business Model Change** Cope with different market dynamics (stablish Collaborations with partner(s) in the value chain to implement new solutions for the end customer)	**As Transformativee** Trans-sectorial dynamics and transgressive processes (works with several partners to implement disruptive changes at a country or global level)
VALUE SOURCE	**Margin pricing:** volumes and market size are key metrics		**Value pricing:** added value and return on investment are key metrics	**New revenue models:** search sectorial new practices, new policies
PRICING	- Price - Cost-Of-Sales calculations - Predictable revenues		- Net Present Value calculations - Uncertain revenues	- Net Present Value calculations - Uncertain revenues

The first vertical of the SCCD strategy, a 'operational driven design strategy', is a diagnostic phase and is the most conservative approach. It gradually implements continuous improvements on existing product and services and refers to the user centred design strategies presented before (Figure 22). An example of this is a waste-free design solution, using the waste from the manufacturing line to sell (focus on service) or include the waste in the product itself (focus on service). The waste cannot be integrated directly in the manufacturing line; designers can develop a parallel strategy to include it in another component or part of the process (even if it is necessary to establish a partnership to process that waste). However, suppose the process changes happen internally using existing teams, in that case, the complexity added to the process is controlled and as a result, return on the investment is fast and easy to measure.

The second vertical of the SCCD strategy (Table 7) - ‘innovation-driven design strategy’, is based on a significant improvement of a product that aims to sustain an existing position in the market, using less material and working on resources efficiency in order to reduce costs. It is a manufacturing centred design processes (Figure 22), and it allows designers to create a loop back to the production stage, keeping the value and functionality of the products in circular savings for longer. An example of this is a collapsible packaging which facilitates the refill and reuse of the packaging several times, keeping the value of the resource longer in the life cycle.

The circular archetypes are focus on the network. Key collaborations are critical to the implementation of the design solution and often the companies invest in startups and outsource strategy and R&D services to prototype and develop the projects and finally marketplace their product and services (PacMan leadership). It is a process innovation full of ambiguity, requiring co-development and partners communication management and because it is based on assumptions and hypothesis the company’s manifest resistance to adopting the strategy, claiming that is difficult to predict the results and share development cost and benefits between partners.

The third vertical of the SCCD strategy (Table 7), ‘operational driven design strategy’, is a transition phase and it is based on an extremely significant technological or business model-oriented innovation, that disrupts the existing market. In a circular context it can transform industries and often creates new markets. It’s a long term and complex transition process of the company business model. It often combines narrowing loops with other design for disassembly, repair or reuse strategies – slowing and closing loops.

To its implementation, the linear approach fails, and the circular requires new internal and external capabilities. The design solution is implemented in strict collaboration with other department and it demands a long labour investment before the profit. It represents high risk to the companies involved and a considerable growth potential since it is focused on a circular identity, branding as unique selling proposition (USP). The return is intangible and uncertain, often based on several financial and business future scenarios, maintained in parallel through time while progressive the problems are solved. This strategy can expose the companies to the benefits of the first movers for the circular economy in their industrial sector, contributing as advisers to policymakers and influencers.

6.2 Lessons learned from the case study: applying SCCD to design the future scenarios

As a starting point to explore the lessons learned from scenarios explored in the previous chapters, a design proposition should focus on user convenience, due to the user's critical role in the circularity of a design solution and consequently, in the success of the product and system design.

Design solutions centred on retaining the product value, adds an additional level of complexity to the design problem and it can be hard because of the need to design all the logistics, partnerships to add value, take-back management systems, monitorization and quality check tools and so on. Every touchpoint of those partnerships must be specially streamlined and for small manufacturers that not always the easiest task.

Design responsibility

As presented, a large amount of produced waste is packaging related, and that is why the raised argument from this research is that the most environmentally friendly attitude is not to value the waste as a resource through recycling, but rather, preventing over-manufacture of plastic packaging in the first place. For that to happen, that packaging cannot be wasted after a single-use. Once used, it will have to survive its own use and be refilled or reused.

R&D is mostly focused on weight reduction, improvement of recycling processes and development of mono-layer materials. Nevertheless, interest in disruptive design solutions is being manifested.

Design requirements

The WisePack case study provided data on some of the design requirements that can be used to develop System- centred Circular-Design solutions. Refill and reuse cycles are facilitated when any type of plastic packaging (and possibly other materials) has the ability to protect themselves throughout its life cycle, especially, after the user consumes the goods it contains to incentivise take-back cycles and actively participative citizens.

In this specific case, a plastic package should assure:

- its ability to assume a self-sustained closed configuration;
- sealing and protecting its interior against contamination during transport;

- its geometrical transformations do not cause plastic deformations in the material, allow it to survive the last stage of its operational cycle and are optimised for reuse;
- it should be capable of safely contain liquid goods;
- to be translucid or to have light colours;
- its label(s) should be kept to a minimum and use non-polluting paints;
- if essential to use adhesives, an easily soluble adhesive should be selected;
- avoid using silicone or rubber components as much as possible;
- to be lightweight;
- to be compatible with bulk sale or non-packaging alternatives.

Active society

Consumers have never been more active in influencing the course of the global economy. Design solutions can promote social change through incentives to change people's behaviour. Providing options that facilitate society to assume a radical environmentally friendly attitude as it already happening with the growing use of bicycles in an urban environment or the policy to reduce the single-use plastic bags at supermarkets drastically.

If the options available are safe, easy to use and convenient for the user, the economy of scale of those solutions can from the production costs and design can be an active participant preventing the single-use of plastic packaging. User habits can change companies. Otherwise, the natural business choice is often the easiest, more profitable way to value the material through recycling after a single-use. The circular economy brings this opportunity to innovate through design.

Retailing areas start to have packaging-free zones. Nevertheless, except some pilot experiences with water dispenser machines, it is only possible to purchase solid goods on bulk sales dispensers.

The goods to be purchased will be transported in paper bags or glass jars, and due to the lack of convenience for the user, these solutions are taking time to affirm their space in the market, since the user must be extremely motivated to store and transport glass containers to the store.

However, from the retailer's environmental responsibility point of view, there are also other points of view with advantages for his business. The storage of large containers, connected to the retail area via distribution tubes, would significantly optimise their storage

and the user would be able to reuse their detergent packaging several times, as was the case with plastic bags.

6.2.1 Design reverse process: how can designers use the SCCD framework?

In this section the SCCD toolbox is presented. This canvas aims to support designers in identifying the requirements, constraints and opportunities of the circular approach. However, it also guides the communication between the designer and the representatives from each department engaged in the transition process from the linear to the circular business model.

The first step is to align the participants in terms of purpose and desired outcome. However, it also guides all employees of the company towards a new culture capable of embracing the indispensable changes. Thus, when this transition will impact the company's business model and, consequently, all its departments, the resistance felt internally will be less. Involving, informing and collaborating are recommended in innovation processes, in order to reduce resistance to change. Thus, all involved elements were prepared to communicate with other stakeholders in the value chain, using the SCCD toolbox to support their arguments and proposals.

Step two helps to visualize the transformation based on the limits of the representation in a linear scheme. It is basically a way of organising thinking and exploring possibilities, but at the same time, start to make the linear/circular transition mentally, before moving on to the details and started narrowing the spectrum of possibilities, which is the goal of step 3.

SYSTEM-CENTERED CIRCULAR-DESIGN
[SCCD] TOOLBOX

STEP 1

DATE

INDUSTRIAL SECTOR/ CLUSTER

PROPOSE:
Explain how this SCCD aims to strengthen a new way of leading business, product development and innovation within the company. A lifetime partner strategy.

DESIRED OUTCOME:
Setting context: stage for the importance of a futureproof Circular Design System strategy.
Setting expectations: what we will deliver and what we won't be delivering through this process.

PRODUCT / PROCESS DESCRIPTION

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

RECYCABILITY (NOW)

 %

REUSABILITY/ REMANUFACTURING (NOW)

 %

WASTE OR PRODUCT TAKE BACK (NOW)

 %

WHAT IS THE METOD(S)? _____

LOCALY? _____

WASTE EXPORTATION? _____

USE REUSED? _____

REPAIRED? _____

AND NEW PARTS? _____

MANUFACTURING WASTE? _____

PRODUCT RETURN (END OF LIFE)? _____

WASTE IMPORTATION? _____

HOURS / DAYS _____ CO-WORK WITH SUPPLIERS

HOURS / DAYS _____ CO-WORK WITH CLIENTS

HOURS / DAYS _____ CO-WORK END USERS

HOURS / DAYS _____ USERS FROM POTENTIAL MARKETS

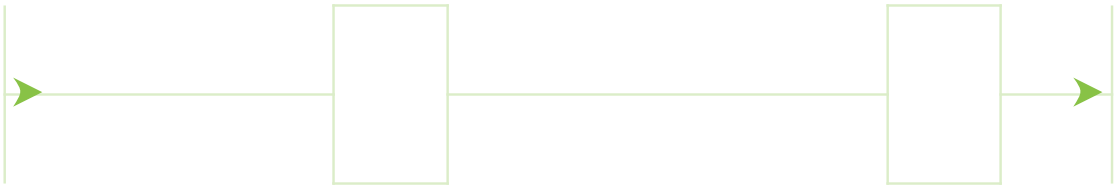
Figure 26. SCCD toolbox part 1

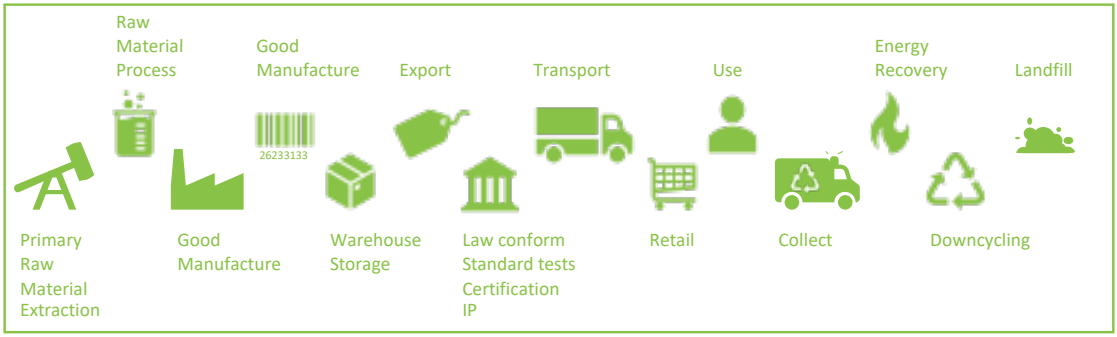
SYSTEM-CENTERED CIRCULAR-DESIGN
[SCCD] TOOLBOX

STEP 2

REPRESENT THE CURRENT LINEAR SUPPLY CHAIN:

Visualize the key stakeholders and highlight your (client) business and the main end-of-live strategy (ies). Ise some of the symbols to represent it.



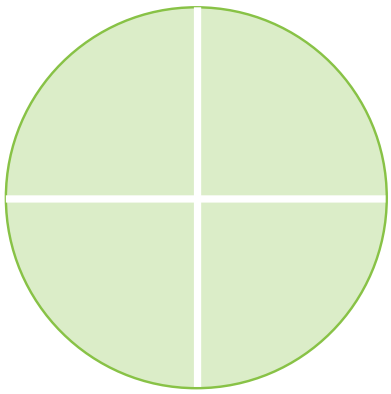


SYSTEM-CENTERED CIRCULAR-DESIGN
[SCCD] TOOLBOX

STEP 3

VALUE PROPOSITION

>> POS-USE PRE-USE >>



OFFER

VALUE PROPOSITION

MARKET SEGMENT

USER REQUIREMENTS

POTENTIAL CHALLENGES

TYPICAL BENEFITS IN THE LONG TERM

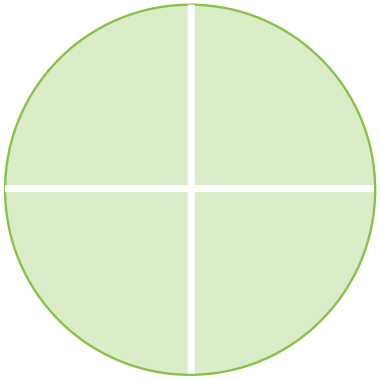
Figure 27. SCCD toolbox part 2 and 3

SYSTEM-CENTERED CIRCULAR-DESIGN
[SCCD] TOOLBOX

STEP 3
continuation

VALUE CREATION

>> POST-USE PRE-USE >>



POTENTIAL CHALLENGES

USP

KEY TECHNOLOGIES / PROCESSES

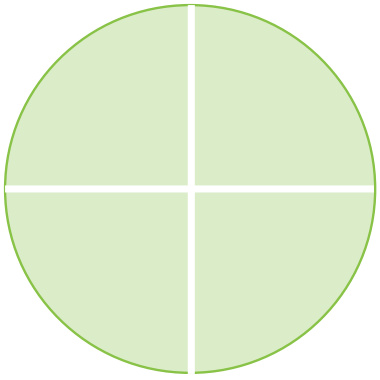
NEW RESOURCES

KEY PARTERS

NEW CHANNELS

VALUE RETAIN

>> POS-USE PRE-USE >>



POTENTIAL CHALLENGES

COSTS

REVENUE FLOWS

INNOVATION STRATEGY

EXIT STRATEGY

DESIGN STRATEGIES

Figure 28. SCCD toolbox part 3

6.2.2 Design solution development: future scenarios to prevent single-use of plastic

To understand these guidelines, the need arises to observe scenarios which are able to indicate potentially feasible ways, in advance to a conversation between the various stakeholders of the value chain and potential design customers.

To this conceptual framework, the importance of developing scenarios that constitute a good ground for discussion about the design process adaptation to this paradigm. In order to facilitate the generation of shared ideas about the direction to take and the choices to make and promote design solution for circular economy. In this sense, it is of extreme importance to introduce the relevant context trends. For the case of preventing the single-use of plastic, the scenarios will have to take into consideration the future trends of evolution design for circular economy previously presented.

In accordance with what has been said about users' behaviour towards repair or reuse, taking-back products, these scenarios will also have to distinguish between different levels of users' engagement. As may be expected, some stakeholders will have to satisfy different needs than others in a shorter time, or with different levels of risk and investment.

The lower and upper thresholds of these levels are evident when we are referring to refill and reuse. Since the second option is most probably more demanding with respect to users' engagement, they will be the primary focus of the following scenario exercise (Figure 29 to Figure 32).

Future Scenario 1: Packaging Design for a Retailer Deposit Return System

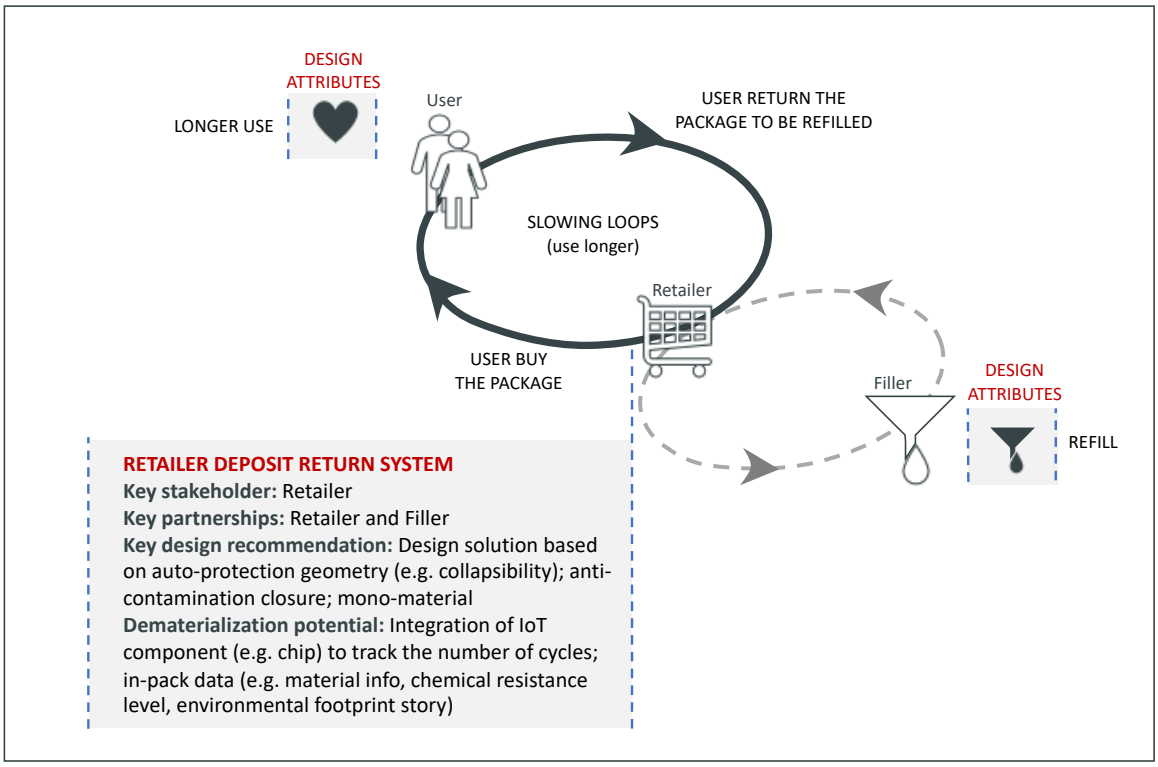


Figure 29. Retailer Deposit Return System

The Retailer Deposit Return System is centred on the user activity and consists on the following process:

1.Key stakeholder activity: USER

The user acquisition of a package with a good inside.

2. Key stakeholder activity: USER

After using it, the user goes to the retail store and returns the empty package.

3. Key stakeholder activity: RETAILER

The retail store is equipped with a return machine that supports its partnership with the filler (the key partners) by monitoring and managing the take-back process.

These machines also read the IoT tool (e.g. chip or material sensitive colour change area) in order to organise the collected packages in an intelligent pallet to be returned to the filler (additional expertise and partnerships required to be considered at a design level).

4. Key collaboration (new value networks): AUTOMATION PARTNER

The intelligent pallet is returned to the filler. Due to the collapsibility characteristic of the packaging the volume inside the pallet is optimised and the package compact configuration protects it from damaging and contamination during transport. Despite the package market non-alimentary goods, the least contamination possible is important, to avoid the need of extensive washing, reducing the water and energetic consumption.

5. Key stakeholder activity: FILLER

The filler can refill the packages' several cycles, reducing the use of virgin and recycled material. The user takes responsibility for their product packaging and retains its value in circulation longer.

Future Scenario 2: Packaging Design for a Non-Packaging Shopping Area Dispensing System

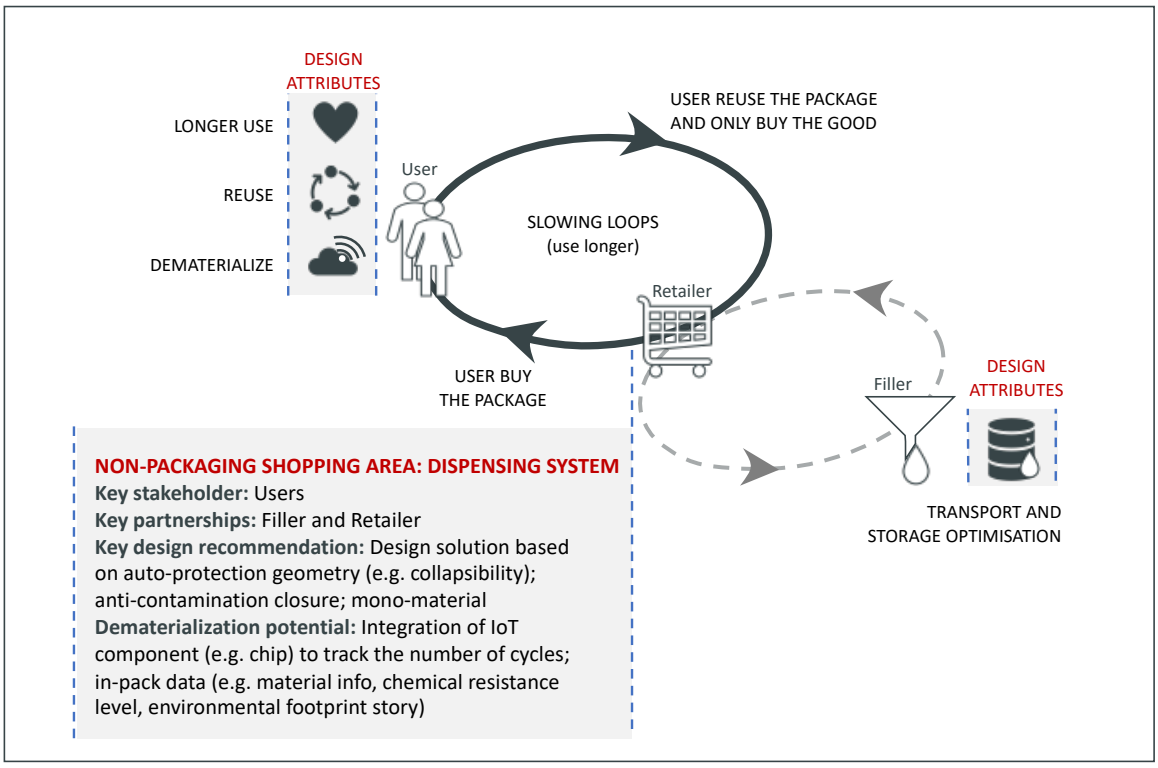


Figure 30. Non-Packaging Shopping Area Dispensing System

The Non-Packaging Shopping Area Dispensing System, is centred on the retailer business model innovation and consists on the following process:

1. Key stakeholder activity: USER

The user acquisition of a package with a good inside.

2. Key stakeholder activity: USER

After use it, the user goes to the retail store with the foldable empty package, as it already happens with the shopping bags and other bags for bulk sale of solid goods.

3. Key stakeholder activity: RETAILER

The retail store is equipped with a dispensing system of several brands. To enable that, the retailer installs an infrastructure that links the non-packaging retailing area accommodating dispensing taps, to a fully automatized warehouse full of large containers, storing the customer (filler) products (Business Model Innovation trends: IoT; Digitalization; Industry 4.0).

This business model is disruptive, since it evolves innovative processes and strategies among all the stakeholders of the value chain, new policy and regimentation and a strong collaborative work. The retailer and the filler are the key partners.

4. Key stakeholder activity: FILLER

The large dimension containers or silos are delivered to the filler, where are refilled and returned to the retailers closing the refill loop.

This business model deeply optimises transport and storage and it carries benefits for business, user, society and environment. However, it also requires an enormous willingness for collaboration between partners, new investments and it implies resistance to change, characteristic of any innovative process.

These two future scenarios emerged from the business models scenarios analysis. During the design reverse process by applying the SCCD framework, several other business model future scenarios emerged. Below, two additional future scenarios are described to illustrate the potential emerged from the use of a structured circular design process – namely the SCCD.

Future Scenario 3: Packaging Design for Subscribe Purchases Within a Return System

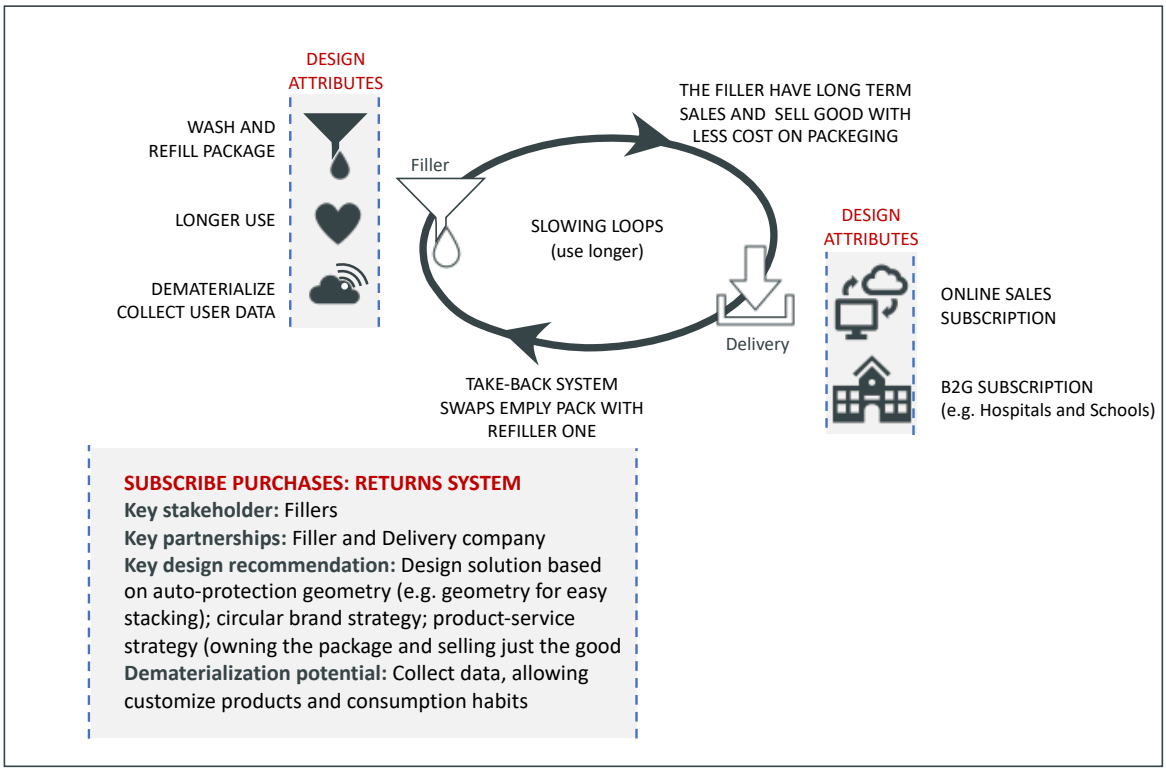


Figure 31. Subscribe Purchases Within a Return System

The Subscribe Purchases Within a Return System, is centred on the filler business model innovation and consists on a digitalization and closing the loop of a conventional, linear business model. The packaging design for this scenario requires larger capacity (e.g. 3 or 5 litres, accordingly to the data collected from interviews) and should consider attributes facilitating the take-back system. It needs to be easy to manipulate and must motivate the workers to collapse, storage and swaps the empty packaging with the filled ones, periodically delivered.

All the future scenarios allow all the stakeholders among the value chain, to transit to a circular business model, adopting circular branding strategies, to answer to the environmentally sensitive customers, premium brand strategies with a significant competitive, social and environmental, and product-service design strategies and solutions.

The future-scenarios generation presented, demonstrates that design cannot only prevent the single-use of plastic by applying circular design strategies, but also be a source of innovation for business models and user patterns, providing systemic and wide-ranging

approaches to designer customers. Supporting their strategic decisions during the design process and, at the same time, facilitating communication between designers and business leaders in order to overcome the risk associated with innovation.

Future Scenario 4: Packaging Design for On-Line Subscription Within a Reward System

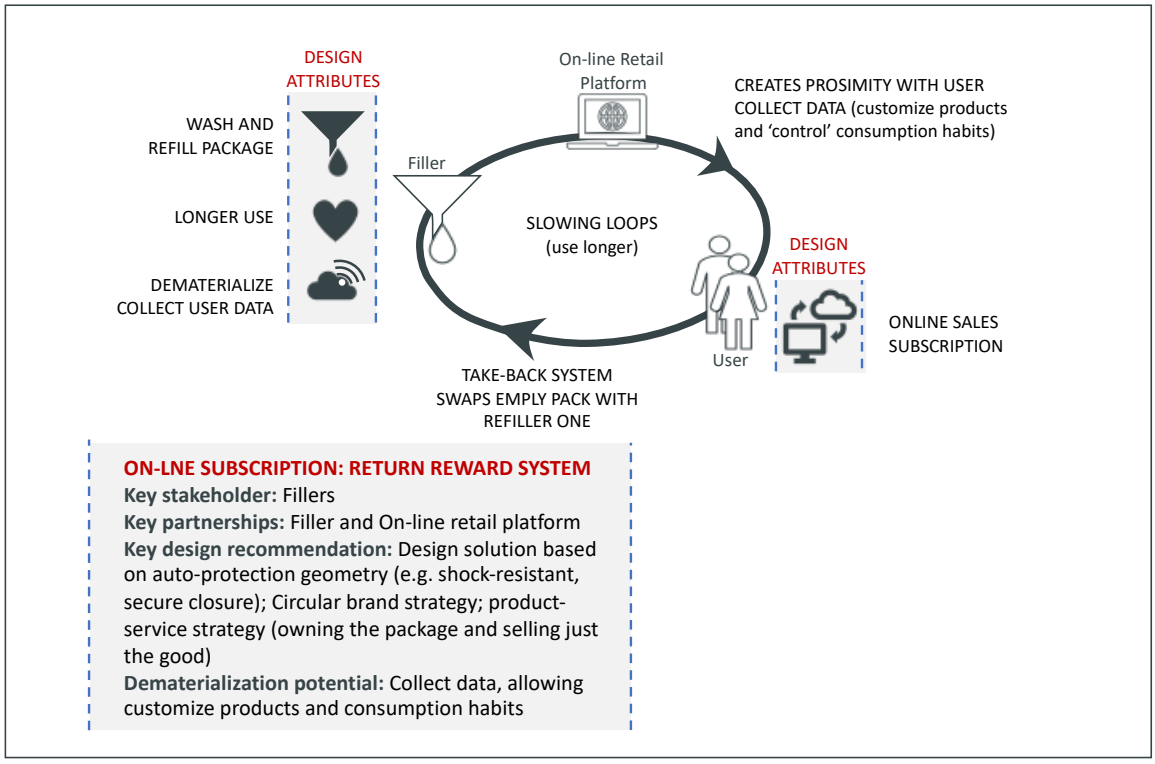


Figure 32. On-Line Subscription Within a Reward System

The On-Line Subscription Within a Reward System, is centred on the filler business model innovation and it allows the company to build direct communication with customers. This is interesting not only at a sales level but also to have customers' direct feedback and collecting data about consumptions habits and desires. A cheaper product or service can be offered to the customers, providing a platform to eliminate product stocks by production on demand.

6.2.3 Future scenarios illustration

To better illustrate the future scenarios (Figure 26 and Figure 27), this section presents a brief story. With it, it is intended to describe the current process (Figure 30), and after detecting that her detergent has run out, Olivia has two alternatives, shown in Figure 31 and Figure 32 of this section.

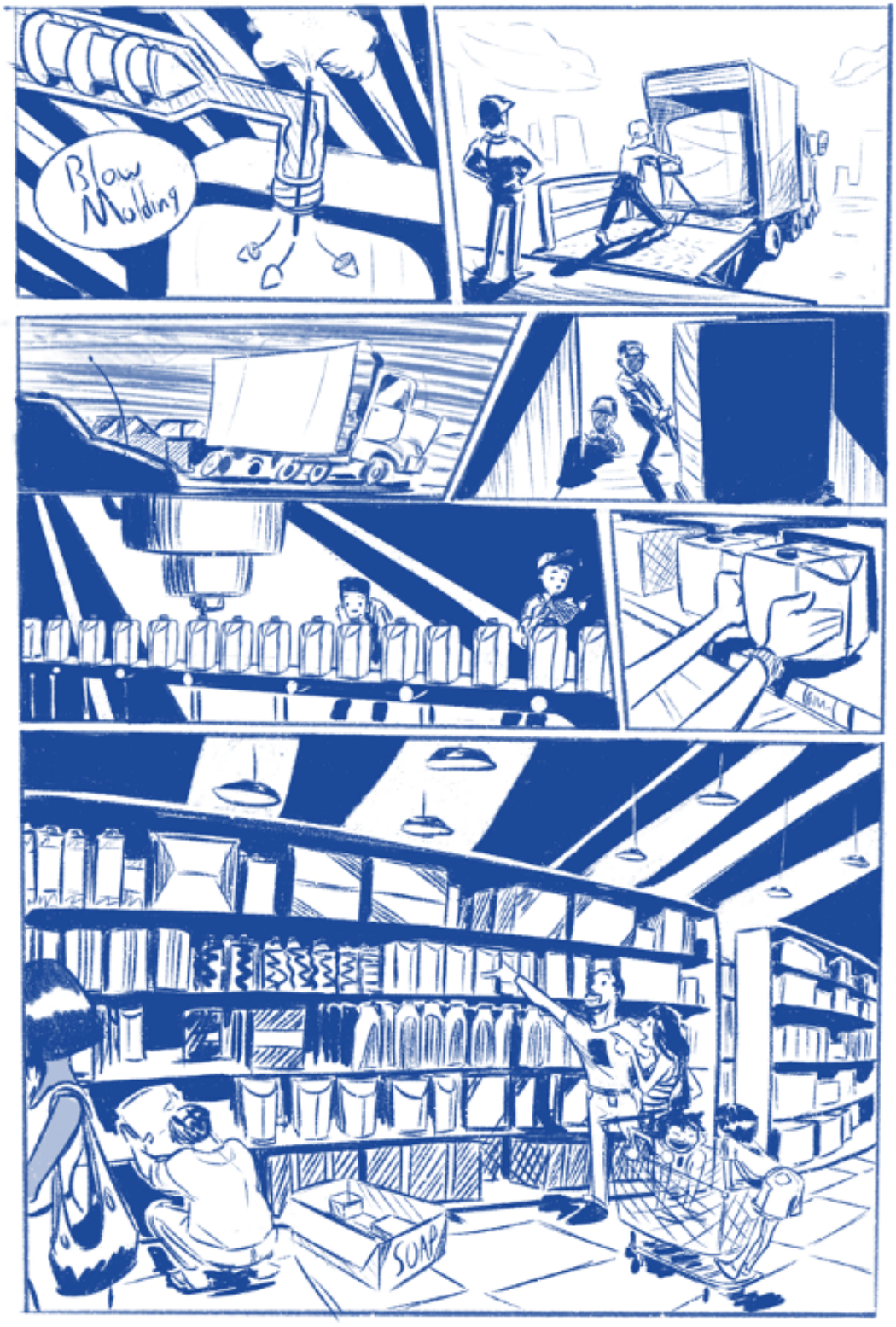


Figure 33. Linear economy

The first panel (Figure 33) of the future scenario design-concept shows the blow moulding process which is the most common manufacturing process for plastic bottles nowadays. To meet the environmental goals, manufacturers have significantly reduced the weight per package. However, reducing the weight of packaging and recycling plastics is not enough to promote the necessary change in an industry that depends on fossil fuels.

In addition, the storage of large volumes of empty bottles both, at the manufacturer warehouse (panel 2, Figure 33) and filler warehouse (panel 4 ,Figure 33) increase significatively the packaging costs. Therefore, plastic manufacturers install their plants close to the costumers (decentralised production model). This was an important step in footprint reduction, special for food and beverage industries because it avoids the contamination during transport and the cleaning before filling the package (panel 3, Figure 33).

The decentralised production model requires greater investments to replicate the production lines of the various customers, disadvantaging smaller companies. On the other hand, if the product is not food, such as bleach or shampoo, the cost of packaging may weigh more than the product itself, making the most advantageous and still existing centralised production model. Therefore, excess volume before filling and after use becomes problematic not only in storage but also in transport. After the package is filled, it is transported again to several retailers (panels 6 and 7, Figure 33) to be stored and placed on the shelves. This logistics process represents also a significant environmental cost and the amount of CO_2 emissions (among others) that promote global warming, and that can be reduced.

The next two future scenarios illustrated in Figure 29 and Figure 30, respectively, both aim to illustrate how can design promote interventions to drastically reduce those environmental impacts and most importantly, to put the change to a circular economy in motion.

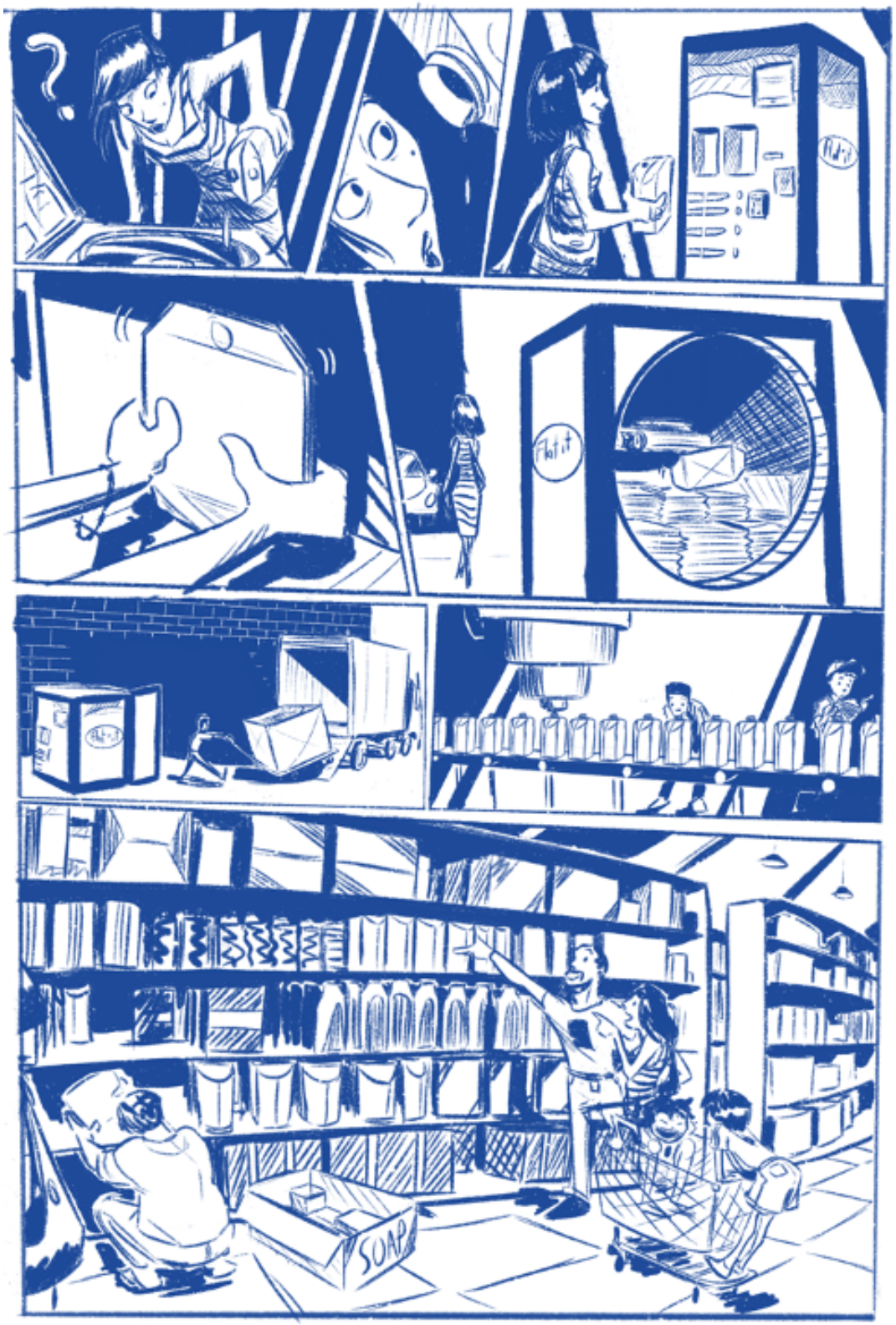


Figure 34. Circular economy: Retailer Deposit Return System

When Olivia is using her laundry detergent and noticed that it finished (Panel 1 and 2, Figure 34), take it back to a Retailer Deposit Return System (Figure 29 and Panel 3, 4 and 5, Figure 34).

As can be observed on the panels 4 and 5 from the Figure 34, the design solution represented is the WisePack concept. The collapsible package motivates Olivia to return it because it adds a very convenient and user-friendly shape, when compared to glass jars or other liquid containers solutions. A flexible plastic bag could be easier to transport but also less easy to store and use while it still has product inside. The collapsible design solution also allows the packaging to protect itself from breakage or deformations during the take-back process (Panel 5 and 6, Figure 34).

Finally, the used package is refilled and sold several times, and through its design, the lifetime of the product is extended. After several cycles, the plastic is recycled, and its resin is added to virgin plastic to produce new products.

Figure 35. Circular economy: Non-Packaging Shopping Area Dispensing System

In the second future scenario (Figure 30 and Figure 35) Olivia saw her detergent has finished, but she goes to the *Non-Packaging Shopping Area Dispensing System.*

Olivia carries one or more foldable packages in her usual shopping bag. When you approach the dispensing system, you can easily open the packaging you want to reuse. Several brands are presented with attractive features, but Olivia is seduced by the one that displays a fantastic interactive video presenting a new sustainable product from her favourite brand.

Panel 6 (Figure 35) shows that, in addition to extending the useful life of the packaging, transport and storage costs, as well as the environmental impacts associated with them, can be drastically optimised. The product is transported in containers from the fillers to the retailer's warehouses where it is channelled to dispensing-taps in the sales-area (*Non-Packaging Shopping Area Dispensing System*).

For retailers, infrastructure investment costs are offset by a reduction in human resources. Generating new business opportunities, with the automation and digitization of their business with all the inherent advantages (for example, waste reduction; flexibility for changes; selling different levels of advertising and optimising shelf space).

Synopsis of chapter 6

Chapter six explores design concepts to validate the design recommendations and guidelines found, while in last section presents the main conclusions of the thesis are drawn, and further work identified.

A SCCD toolbox is presented. Those canvas aim to support designers in identifying the requirements, constraints and opportunities of the circular approach. However, it also guides the communication between the designer and the representatives from each department engaged in the transition process from the linear to the circular business model.

CONCLUSIONS

Closing remarks

Activities over the past several years, clearly show that Circular Economy is emerging as an economic strategy rather than a purely environmental strategy. In the multidisciplinary nature of the design approach, not only are perceptive attributes considered, such as form, colour, texture, on an aesthetic and semiotic level; but also state-of-the-art of technology and socio-environmental elements and business model's transformations are constraints to the design process. Consequently, design may be a source of innovation to establish circular business models.

Moving from linear economy to a circular economy has felt the combined effects of changes in design. Rather than being destined for disposal, materials should maintain their utility and value and flow back into the cycle.

The relationship between design and actual success of business has been often addressed. Nevertheless, the overall objective of this study is to explore design strategies related with the circular-economy, where product-design is a source of innovation to business models, impacting on a system level, the plastic-packaging value chain. The circular-design approaches options are expanding at a significant rate, creating a multitude of different evolution paths that have been nonetheless compatible with the current products' ecosystems during the present business models transformation.

The research problem of this thesis is: "How can design be a source of innovation to transform businesses models accordingly to circular economy principles?".

The problem was approached by addressing WisePack, a collapsible packaging solution. The case study of a packaging solution is at the basis of the business model analysis, aiming to reverse the design process and establish first-hand the design guidelines for circularity.

The analysis was based on the conceptual framework of System-Centred Circular-Design, in order to define circular-design recommendations to integrate circular economy principles in an early stage of the design process.

This framework is important because once product specifications are being made, only minor changes are usually possible, but also, because design processes tend to have embedded a user centrality. In fact, this is almost intuitive to derive since ultimately, if a

given product or service does not fulfil the user expectations, it will most probably be condemned to failure, independently of whether the client's expectations are met.

In essence, a deep understanding of general design parameters, innovation in products has to emerge, taking into consideration human aspirations and worries. Nowadays, it means answering to a more participative, more environmentally-conscious and more demanding end-user. From the business point of view (economical vector of the sustainability), the circular business-models are being advocated but as yet, they are not widely practised. Today's world lives beyond large changes within topics such as industrial symbiosis, zero waste goals, non-energy industrial raw materials and bio-waste, which influence all activity sectors, not to mention, people's everyday lives.

The design problem was formulated based on:

- the fact that over the years, plastic packaging demand has increased drastically, in various sectors of the economy. The plastic-packaging industry model of consumption is linear and dates to the Industrial Revolution. Plastic Packaging global economy develops around the model of consumption of *take-make-use-dispose*, but various social, economic and environmental factors mean that it is no longer sustainable;
- to increase recycling has been often pointed as the main strategy to scale up the circularity of plastics packaging, but the industry has no demand such a large amount of recycled material;
- to replace plastic with alternative material results in a significant negative environmental impact and the anti-plastic sentiment is distracting us from the environmental benefits of plastic.

The application of the mentioned methodologies induced the emergence of the circular-design recommendations, which were derived from the look at the considerations of circular economy principles, that should be integrated in an early stage of the design process and understand how it impacts the value chain and the life cycle of the product and services.

The complexity of circular design derives fundamentally from the system approach that requires innovation and therefore, changes in the existing patterns and habits, changes in the behaviour of producers as well as consumers. Design-for-repair and Design-for-recycling. Rethinking products as a product-service solution can result in a total or partial

dematerialization of some products and commercialize it as a service or a product with a complementary service.

Furthermore, the most recent techniques were used to evolve to the solution from emerging design recommendations. In particular the used of circular business model canvas and the scenario-based technique consisted on developing future scenarios by describing typical interactions on the supply chain (data arising from the interviews and value chain analysis).

This allowed the identification of the three key elements that any circular business model should ideally have, and that consequently shape the design process: circular value creation (to include one or more ways to close, slow or narrow resource loops); to make use of value propositions that enable circularity (depends on the needs and motivations of customers); and to be surrounded by circular value network (all stages of a product life cycle are connected in a way that assures that the product and its resources are maintained inside the economy).

The conceptual framework is entitled by system-centred and circular-design (SCCD), and it intends to understand the advantages of the adoption of a circular design framework as well as the potential benefits and archetypes of the circular product value chain.

This interactive process gave feedback to the general value chain typologies of the plastics industry with a centralised production, and defined theory and detailed knowledge about refilling and reusing plastic packaging. Slowing loops of circular economy strategies, poorly approached by this industrial sector.

At a product design level:

- *The technical limitation of current solutions to promote the single-use of plastic.* Most packaging in those markets, do not maintain its configuration after reducing the volume (collapsing or other techniques). It requires the cap (often made in a different material) to remain in its compact configuration and it gets damaged, unable to be reused, all that can be done with this amorphous material is to recycle. The ability to contain and protect a product change after consumption is highlighted, only because of the stress that it goes through during the collecting, transport and storage stages, and not due to the use of the package.

Recycling allows packaging waste to be recovered, but the amount of waste is not reduced. The packaging industry has never hesitated to manufacture disposable packaging.

On the contrary: the ease of production and the cost of packaging favours a disposable and recyclable end of life. Future trends by applying the ethnographic methodology and recommendations to SCCD strategies result to propose a conceptual ground to design the future scenario of single-use of plastic packaging.

Relevant information to retain from interviews and observation (Figure 19) are the differences of interest between stakeholders. The level of collaborations demanded on a context of a circular economy may instigate resistance to change and block the implementation of disruptive circular-design concepts. If the filler considers the shelf and brand trust mandatory variables, it can block the transition of all the other stackholders to a circular business model. Nevertheless, it is interesting to see that the position of the user's perception also favours environmental communication and the brand's popularity, adopting a clear position in favour of cost reduction and waste reduction. The manufacturers place greater emphasis on reducing transport costs than to the popularity of their brand and environmental marketing, and retailers place greater importance on the brand's popularity, on environmental communication as a sales tool.

Hereupon, the cross-analysis addressed during the development of the case study and the scenarios description for circular business models provided a deeper understanding of the synergy's characteristics of this design problem, but it also validated the design requirements and business points of view among the value chain.

The main contribution of this thesis is the definition of the SCCD. Its goal is to present guidelines that support the creation, analysis and execution of specifications and the formal process of circular designs. It represents specifications and design strategies completely and concisely. The adaptation of the SCCD approach to any design problem requires characteristics of value proposition, value creation and value retain, modularity and several circular-design archetypes to extend the products life cycle. Therefore, it can conduct and guide the design process towards a circular approach, reducing the uncertainty and supporting the innovation communication between stackholders.

As result of the analysis, endurance cycles, shorter than the conventional loops (Figure 22) are explored through repair, reuse and remanufacturing design strategies. The relation between the several circular business models archetypes were explored as bringing to a design solution. Short loops as in the design for reuse strategy can quickly return to the use phase. Slightly longer loops such as in the design for refill strategy can extend product

lifetime, by design for refill strategies where the same packaging (or any product) goes back to other stakeholders of the value chain several times during its life-cycle.

The product chain revealed to be useful to support designers in the definition of the product circular-strategy. Once defined, it will be assessed whether innovative business opportunities exist and if through Design, competitive advantages can be generated according to a circular perspective. In a supply chain, the flow of materials and, consequently, costs and revenues flux will be evaluated (purchase and sale). In the circular economy, it is also important to assess transfers of value from one segment to the next. This decision process on the part of the designer is usually called by the design thinking of mapping.

The important observation resulting from these analyses is that any visible value in the form of materials, commercialized services, monetary exchanges or key partners/suppliers, results in commercial transactions. These transactions are not always monetary, and a design solution must be able to project accordingly to this ecosystem approach. For example, one partner has a competitive advantage over the other due to the conditions or characteristics of the transaction. The objectives of these transactions allow the designer to find design attributes, specifications that respond based on the materials that flow between segments of a value chain, and to what needs these transactions are intended to meet.

Finally, it can be concluded that design can be a source of sustained and/or disruptive innovation and, depending on the specific case of analysis of this research, it can prevent the single-use of plastic bottles.

It was concluded that the proposed model is a valid tool for the design of circular business. Confirming the primary and secondary objectives of this study. Showing that design principles, related to circular-economy concepts, become a source of innovation, and the SCCD model and toolbox, support the businesses models transformation.

Limitations

To summarize, two concluding remarks are necessary. Firstly, it is important to stress that disruptive innovation should be seen in an integrated manner to design process, so to maximize the potential for satisfying the companies need and users' aspirations – in the spirit of the SCCD approach. Secondly, from a social perspective, it is expected that the

new retailer options will be characterised by a better environmental profile than its contemporaneous, in order for the same service – make good available – to be made accessible with a smaller environmental burden.

Accordingly, the related environmental performance indicator for all the stakeholders among the value chain must be lower, the product/ service lifetime should be slower in relation to the principles associated with circular design being fulfilled.

Design solutions must drastically optimise the resources involved in the products, by simplifying the role played by manufacturers, distributors, retailers, and users, promote an increase in the number of cycles of use of the product, as well as increasing the percentage of recovery for recycling. Finally, from general design parameters, innovation in products has to emerge, taking into consideration human aspirations and worries.

In a linear economy, the situation is clearer, but a circular economy is highlighting new challenges and tensions, which need to be dealt with as the transition evolves. Despite all this, circular or not, high volumes of plastic made from oil or using modern human slavery is a fake cheap. Personally, I believe that research, technology and progress will help humanity do it better. Design is fundamental in including the anthropological and social dimensions to the process of change.

Additional note added later due to the Covid-19:

> *"Governments and central banks are asking taxpayers to underwrite national firms through their stimulus packages, creating a huge and ongoing incentive to favour them. And the push to bring supply chains back home in the name of resilience is accelerating. On May 12th Narendra Modi, India's prime minister, told the nation that a new era of economic self-reliance has begun. Japan's covid-19 stimulus includes subsidies for firms that repatriate factories; European Union officials talk of "strategic autonomy" and are creating a fund to buy stakes in firms. America is urging Intel to build plants at home." (The Economist, 2020)*

Regionalise supply chains concentrate risk and with that economy of scale is lost. Supply chains are more resilient if diversified, which is another factor that favour change and can accelerate the transition to a circular economy. Business in particular and economy in general, are being rethought based on a single certainty: we need to do differently.

Further work

Although the contribution of the research work is to identify the critical guidelines for product design in order to be aligned with the plastic industry demands to promote the shift from a linear to a circular economy. Focus on design solutions to ensure plastic bottles refill and reuse.

The orbital outcomes of the thesis are expected to improve current knowledge on:

- academic level, design strategies were categorized to be a source of change and a three steps implementation strategy is draft as a recommended strategy;
- industry and value chain levels, business-models innovation were discussed and the SCCD tool developed, to maps and guide the business to remodel their value proposition characteristics, rethink their value creation and value retain in a circular way, adapt current offer and develop new solutions accordingly to modularity principles and several circular-design archetypes, to extend the products life cycle.

According to the future scenarios that illustrate the main findings, changes or new collaborations with a circular-design strategy in mind, shape business model elements, outlining business strategies that support decision maker in the redefinition of their circular economy approach. The lower and upper thresholds of this gradation are thus when we are referring to refill and reuse. Since the second option is most probably more demanding with respect to user's engagement.

Nonetheless, the exact specifications of these scenarios are perceived to need further development, thus being suggested as a possible line of future work.

Further Work 1 - Pilot Phases: Establishment of partnerships to promote a demonstrative effect. Goals:

- test the implementation model of the SCCD tools;
- establish new collaborations with a circular design strategy in mind;
- outline business strategies that support the decision-maker in redefining his circular economy approach;
- engage the user in the take-back phase, to close the loops.

Further Work 2 - Design-Competitions, Publications and Workshops: Stimulate knowledge-transfer actions between academia and industry. Goals:

- training designers who shape the circular economy and sustainable growth, since they support companies with a very clear sustainable vision and phased objectives;
- support companies to relocate to a level of added value and support them positioning in markets with a sustainable future;
- promoting initiatives that allow companies and citizens to contribute to new policy development and promote the change in the economy.

Design can support decision makers to visualize several strategies and identify how to overcome barriers to capture and maintain value. Designers are co-shapers of the circular economy and sustainable growth, since they support companies with very clear sustainable vision and staged goals (operational, performance and innovation-driven, design strategies).

The design framework presented as the main result of this study, SCCD, was developed to guide designers through the circular design implementation. It is a fundamental tool since circular economy strategies, like design, are not measured and quantified, they are a direction. If companies want their direction to be sustainable and competitive, circular-design strategies and solutions have to become the everyday operations of the company across departments.

The design for circularity mission is oriented towards innovation strategies, based on industrial structures, collaborative ecosystems, which defines how to design solutions end up integrating with manufacturing and consumption based around a sustainable economy. A global opportunity such the one we are currently experiencing, allows companies and citizens to contribute to new policy development and, in fact, promote the change. Design for circularity, has to include in its process moments to actually rethink the structures, processes and methods that are the ‘normal procedures’ in this economy, and what is a more interesting form of design, distribution and manufacturing; and which are the key partners - how they manage a system along the entire way to deliver convenience to consumers and motivate them to participate.

Circular economy is emerging as an economic strategy. Changes are absolutely necessary to prevent a climate crisis and design strategies need to support business and policymakers to engage the consumers, not only to participate but also to define missions themselves, whether they are built around digital, product or service design.

REFERENCES

Alaerts, L., Van Acker, K., Rousseau, S., De Jaeger, S., Moraga, G., Dewulf, J., De Meester, S., Van Passel, S., Compernolle, T., Bachus, K., Vrancken, K., & Eyckmans, J. (2019). Towards a more direct policy feedback in circular economy monitoring via a societal needs perspective. *Resources, Conservation and Recycling*, *149*, 363–371. https://doi.org/10.1016/j.resconrec.2019.06.004

Andrews, D. (2015). The circular economy, design thinking and education for sustainability. *Local Economy*, *30*(3), 305–315. https://doi.org/10.1177/0269094215578226

Ashby, M. F. (2012). *Materials and the Environment: Eco-informed Material Choice*. Elsevier.

Ayers, R. U. (1994). *Industrial Metabolism: Theory and Policy*. 8.

Bakker, C. (2019). *Products That Last: Product Design for Circular Business Models*. Laurence King Publishing.

Bililies, T. (2016). *Centralization Versus Decentralization*. https://emarketing.alixpartners.com/rs/emsimages/2016/pubs/LOE/AP_Centralization_versus_Decentralization_Apr_2016.pdf

Blomsma, F., & Brennan, G. (2017). The Emergence of Circular Economy: A New Framing Around Prolonging Resource Productivity. *Journal of Industrial Ecology*, *21*(3), 603–614. https://doi.org/10.1111/jiec.12603

Bocken, N. M., De Pauw, I., Bakker, C., & van der Grinten, B. (2016). Product design and business model strategies for a circular economy. *Journal of Industrial and Production Engineering*, *33*(5), 308–320.

Boni, V., & Quaresma, S. J. (2005). Aprendendo a entrevistar: Como fazer entrevistas em Ciências Sociais. *Em Tese*, *2*(1), 68–80.

Bumble, S. (2019). *Computer Simulated Plant Design for Waste Minimization/Pollution Prevention*. CRC Press.

Chalmin, P. (2019). The history of plastics: From the Capitol to the Tarpeian Rock. *Field Actions Science Reports. The Journal of Field Actions*, *Special Issue 19*, 6–11.

Charter, M. (2018). *Designing for the Circular Economy*. Routledge.

Christensen, C., McDonald, R. M., Altman, E. J., & Palmer, J. (2017). Disruptive Innovation: Intellectual History and Future Paths. *Academy of Management Proceedings*, *2017*(1), 14218. https://doi.org/10.5465/AMBPP.2017.14218abstract

Circular Economy System Diagram. (n.d.). Retrieved 22 October 2020, from https://www.ellenmacarthurfoundation.org/circular-economy/concept/infographic

Clapp, J. (2012). The rising tide against plastic waste: Unpacking industry attempts to influence the debate. In *Histories of the Dustheap: Waste, Material Cultures, Social Justice* (pp. 199–226).

Clayton M. Christensen, Michael E. Raynor, & Scott D. Anthony. (2003, March 9). *Six Keys to Building New Markets by Unleashing Disruptive Innovation—Harvard Business School Working Knowledge*. https://hbswk.hbs.edu/item/six-keys-to-building-new-markets-by-unleashing-disruptive-innovation

Clift, R. (2015). *Taking stock of industrial ecology*. Springer Berlin Heidelberg.

Coursera. (2020). *Circular Economy—Sustainable Materials Management*. Coursera. https://www.coursera.org/learn/circular-economy

Dalenogare, L. S., Benitez, G. B., Ayala, N. F., & Frank, A. G. (2018). The expected contribution of Industry 4.0 technologies for industrial performance. *International Journal of Production Economics*, *204*, 383–394. https://doi.org/10.1016/j.ijpe.2018.08.019

De los Rios, I. C., & Charnley, F. J. S. (2017). Skills and capabilities for a sustainable and circular economy: The changing role of design. *Journal of Cleaner Production*, *160*, 109–122. https://doi.org/10.1016/j.jclepro.2016.10.130

Ellen-MacArthur-Foundation. (2015). *Ellen-MacArthur-Foundation-Towards-the-Circular-Economy: Business Rationale for an Accelerated Transition-vol.1.pdf*.

Espada, A. (2020). *Design as a Source of Innovation to Establish Circular Models: An Opportunity to Prevent the Single Use of Plastic* [Chapter]. Handbook of Research on Driving Industrial

Competitiveness With Innovative Design Principles; IGI Global. https://doi.org/10.4018/978-1-7998-3628-5.ch014

Espada, A., Rosado, L., & Vargas, L. (2007). *Método de redução e controlo ds tensões envolvidas na colapsibilidade de uma embalagem totalmente colapsável* (Patent No. PT103553B). https://patents.google.com/patent/PT103553B/pt?q=colapsibilidade&oq=colapsibilidade

Espada, A., Rosado, L., & Vargas, L. (2008). *Collapsible package* (WO Patent No. WO2008020776A1). https://patents.google.com/patent/WO2008020776A1/en?oq=WO2008020776A1

European Commission. (2016, July 5). *Critical raw materials* [Text]. Internal Market, Industry, Entrepreneurship and SMEs - European Commission. https://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical_en

European Commission. (2018a, January 16). *A European Strategy for Plastics in a Circular Economy*. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52018DC0028&from=EN

European Commission. (2018b, May 28). *Single-use plastics: New EU rules to reduce marine litter* [Text]. European Commission - European Commission. https://ec.europa.eu/commission/presscorner/detail/en/IP_18_3927

Ferrão, P. M. C. (2007). Industrial Ecology: A Step Towards Sustainable Development. In M. S. Pereira (Ed.), *A Portrait of State-of-the-Art Research at the Technical University of Lisbon* (pp. 357–383). Springer Netherlands. https://doi.org/10.1007/978-1-4020-5690-1_23

Foster, S. (2018, May 17). *RECOUP Plastics Recycling Conference focuses on building the circular economy | California Resource Recovery Association (CRRA)*. http://www.crra.com/recoup-plastics-recycling-conference-focuses-building-circular-economy

Global Commitment. (n.d.). New Plastics Economy (En-GB). Retrieved 22 October 2020, from https://www.newplasticseconomy.org/projects/global-commitment

Gorissen, L., Manshoven, S., & Vrancken, K. (2014). Tailoring business model innovation towards grand challenges: Employment of a transition management approach for the social enterprise “re-use centers”. *Journal of Global Responsibility*, *5*(2), 289–311. https://doi.org/10.1108/JGR-03-2014-0012

Graedel, T. E., & Lifset, R. J. (2016). Industrial ecology’s first decade. In *Taking Stock of Industrial Ecology* (pp. 3–20). Springer, Cham.

Guerra, I. C. (2006). *Pesquisa qualitativa e análise de conteúdo: Sentidos e formas de uso*. Lucerna.

Hammersley, M. (2016). *Reading Ethnographic Research*. Routledge.

Handl, G. (1972). *DECLARATION OF THE UNITED NATIONS CONFERENCE ON THE HUMAN ENVIRONMENT*. 11.

LeCompte, M. D., & Goetz, J. P. (1982). Problems of Reliability and Validity in Ethnographic Research. *Review of Educational Research*, *52*(1), 31–60. https://doi.org/10.3102/00346543052001031

Lyle, J. (1994). *Regenerative Design for Sustainable Development—John Tillman Lyle—Google Books*. https://books.google.be/books?hl=en&lr=&id=qB3v3gYofSUC&oi=fnd&pg=PP13&dq=John+T.+Lyle&ots=Dd8dit8N9i&sig=kr9OJVc49P-Pl8R0Neu1bsDtUMw&redir_esc=y#v=onepage&q=John%20T.%20Lyle&f=false

Manninen, K., Koskela, S., Antikainen, R., Bocken, N., Dahlbo, H., & Aminoff, A. (2018). Do circular economy business models capture intended environmental value propositions? *Journal of Cleaner Production*, *171*, 413–422. https://doi.org/10.1016/j.jclepro.2017.10.003

McDonough, W., & Braungart, M. (2010). *Cradle to Cradle: Remaking the Way We Make Things*. Farrar, Straus and Giroux.

MIT Documenting Culture. (n.d.). *Readings | Documenting Culture | Anthropology | MIT OpenCourseWare*. Retrieved 14 May 2020, from

https://ocw.mit.edu/courses/anthropology/21a-337j-documenting-culture-spring-2004/readings/

Moreno, M., De los Rios, C., Rowe, Z., & Charnley, F. (2016). A Conceptual Framework for Circular Design. *Sustainability*, *8*(9), 937. https://doi.org/10.3390/su8090937

Myers, M. D. (1999). Investigating Information Systems with Ethnographic Research. *Communications of the Association for Information Systems*, *2*. https://doi.org/10.17705/1CAIS.00223

Norman, D. A., & Verganti, R. (2013). Incremental and Radical Innovation: Design Research vs. Technology and Meaning Change. *Design Issues*, *30*(1), 78–96. https://doi.org/10.1162/DESI_a_00250

Nußholz, J. L. K. (2017). Circular Business Models: Defining a Concept and Framing an Emerging Research Field. *Sustainability*, *9*(10), 1810. https://doi.org/10.3390/su9101810

Osterwalder, A., & Pigneur, Y. (2010). *Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers*. John Wiley & Sons.

Pardo, R. (2018). A long-term strategy for a European circular economy – setting the course for success. *IEEP and Jean-Pierre Schweitzer, Product Policy and Circular Economy Office, EEB*, 33.

Plastics Pact. (n.d.). New Plastics Economy (En-GB). Retrieved 22 October 2020, from https://www.newplasticseconomy.org/projects/plastics-pact

PlasticsEurope, Ass. of P. M. (n.d.). *PlasticsEurope Annual Review 2017-2019*. Retrieved 19 November 2019, from https://www.plasticseurope.org/en/resources/publications/498-plasticseurope-annual-review-2017-2018

Ragaert, K. (2019, July 11). *How to make the Plastic Rehab happen—A cleaer view on today's challenges for sustainable plastics industry*.

Rogers, R. (1996). Cities for a small planet. *World Heritage Review*, *No. 3*, 68–77.

Kalmykova, Y. (2019). *Combining Industrial Symbiosis With Sustainable Supply Chain Management for the Development of Urban Communities—IEEE Journals & Magazine*. https://ieeexplore.ieee.org/abstract/document/8691443

Selke, S. (2018, December 6). *Plastic is the most environmentally-friendly packaging material*. ..Packaginginsights.Com/. https://pi.cnsmedia.com/a/v54lhSj7KzQ=

Sullivan, L. H. (1922). *The tall office building artistically considered*. Minneapolis.

Tester, J. W. et al. (2005). *Sustainable Energy—Choosing Among Options*. The MIT Press. https://mitpress.mit.edu/books/sustainable-energy

The Economist. (2020, May 14). Has covid-19 killed globalisation? *The Economist*. https://www.economist.com/leaders/2020/05/14/has-covid-19-killed-globalisation?cid1=cust/ednew/n/bl/n/2020/05/14n/owned/n/n/nwl/n/n/EU/473988/n

TROCH, P. D. (2016, December 19). *Policy and strategy for raw materials* [Text]. Internal Market, Industry, Entrepreneurship and SMEs - European Commission. https://ec.europa.eu/growth/sectors/raw-materials/policy-strategy_en

Vargas, L. A. B. P. (2004). *Embalagem colapsavel* (Patent No. PT102805A). https://patents.google.com/patent/PT102805A/en?q=sistema+de&q=fole%2c+embalage%2c&scholar&oq=sistema+de+fole%2c+embalage%2c

Wiesweg, M. (2019, July 12). *Polymer Market Trends—Outlook and Sustainable Impact*.

APPENDICES

APPENDIX A - Interview synopsis: manufacturing company/ centralised (I1; I2; I3)

Interview Documentation (1)

"Supporting draw..."

Introduction (5 MIN.)

[redacted], Marinha Grande, Portugal	Org. Type: Manufacturer (decentralized)
[redacted], Production Manager	08.10.19 / 10.03.20 / 13.03.20

Get to know (5 MIN.)

(translated from Portuguese)
+ small company
+ around 50 employs
+ 3 production lines, blow molding. 1 injection machine for caps and other pieces
+ Packaging: pharma and detergents
+ >50% HDPE but also PP; PVC
+ Centralized production
+ Material and moulds suppliers are key partners
+ Production, and Lab (standards, not other)
+ No difference from competition (need to differentiate)
+ The owner goes to sectorial meetings

+ What about the materials,, do you think you will use different materials than HDPE, PP, PVC?

"Maybe we tart using PET more often, but we need new machines."
And for multilayers for certain pharma products because of the chemical reaction inside the packaging. Some products require specific chemical resistance characteristics. It can be done with additives."

+ What is the bigger constraint for the business, what is the main challenge? Why? How did the company try to solve it? When did an innovation occur?

"Our business fell the price pressure form the oscillations of the oil price barrel from one side and the customers from other."
"Transport is a big issue for us. If we can reduce the weight per package we have larger margins."

Opening Questions (10 MIN.)

+ I would like to better understand how the company started to actuate in a centralized business model? Do you imagine that changing?

"I t has been always like centralized, because of the costs. There is not problem with contamination during the transport, that is only for food and beverage packaging."
"Our customers want low prices, I don't see it changing in the future. Their product cost less than the packaging."
"In the client ask something different we do. But we are not proactive searching for innovation."

"Add answer here..."

Interview Documentation (2)

Savvy Green Eco-Clean Laundry Detergent Flexible packaging

TIDE Eco-Box Concentrated

Design and Innovation (handling the prototype) (30 MIN.)

08.10.19 / 10&13.03.20	Maringa Grande, Portugal

Design and value creation	Process and operations	Partners and network	Craving to innovate	Perception / expectations	Reflection
"Maybe we should change the ribs and make it deeper." "The closing mold are can be in the opposite direction to facilitate the closing and control the forces." "This would have a massive impact in the cost with transportation! We don't care that much about the environmental speech, that is for larger companies!" "The value is on our cost reduction and growth of our margins."	"This is possible to produce with the current machinery and materials." "This nee to be tested in production (attempt/ error) and reduce the wall in the foldable parts."	"For the customer is similar to the existent process. We actually would have one more step in his production line – the opening before fill it." "Yes, clients in the (Portuguese) islands are very interested in reduce cost of transportation. And the other solutions, for example flexible packaging need new processes and machines. Bigger changes." "And the customer do not like chemicals in flexible packaging. They are afraid that it brakes. TIDE created a cardboard box to make the packaging stand during use, but not in production."	"We need to differentiate. But with realistic innovation!" "Some clients want to try different geometries and the process is long and expensive, mostly the mold and HR. Often we start projects and the client quit. And we lose our investment."	"Refill what this package? No! Recycle? (...) But we sell less!" "If the reduction in transportation costs yields a greater return than what is lost in sales ..." "Charge to license per each time the packaging is refilled?"	"Thus, we would achieve a reduction in transportation costs and, although we may sell less, each product would generate gains several times. Up to 7 times." "This can be interesting! Mainly because they are changes in geometry and do not require significant investment in terms of technology, material, machine or mold."

Interview Documentation (3)

Ideas (5 MIN.)

The greater for a greater packaging capacity is an advantage. 3 or 5 liters can be tested, to see a support package in the arm area.

The customer can send a container with 100 liters to the islands and both and also reduce his costs.

"Add answer here..."

Conclusion (5 MIN.)

Economic, societal and environmental value:
The cost of the package is often higher than the good itself, in household and personal care market segments. The same motive that fillers opt for centralized production, make them also put economic interest before societal or environmental.

Reduce cost in transportation, reducing volume:
Flexible packaging competes with collapsible geometry but fillers of non-alimentary goods prefer standing packaging. Because if demands minimum changes in the production line and low investment.

Weight reduction:
PET is very used because it allows very thin walls and significative reductions of the weight per package. Pet is also 100% recyclable. But PET is not flexible enough for foldable geometries. It breaks in the critical areas of the packaging.

Collapsibility/ foldability, reducing volume:
Design solutions that reduce the volume before and after filling is very interesting.

"Supporting draw..."

Supplied in reels, reducing the volume during transport.

APPENDIX B - Interview synopsis: manufacturing company/ decentralised (I4; I5)

Interview Documentation (1)

"Supporting draw…"

Introduction (5 MIN.)

[redacted], Cascais, Portugal	Org. Type: Manufacturer (centralized)
[redacted], Technical Manager	30.09.2019

Get to know (5 MIN.)

(translated from Portuguese)

+ It is the third-largest rigid plastic processing company in Europe and is among the 10 largest in the world.
+ 59 plants, in 16 countries Brazil, Belgium, Canada, Czech Republic, France, Italy, Poland, Mexico, Netherlands, Portugal, Russia, Spain, Ukraine, United Kingdom, USA, Vietnam.
+ Clients: Procter &Gamble, Henkel ,Coca-Cola, Danone, L'Oréal or ketchup Heinz
+ First in Europe implementing centralized business model: "hole-in-the-wall"
+ R&D, raw-material, machines and robots, and moulds suppliers are key partners
+ Sustainability is at the center of our Corporate Values.
+ Mostly rigid plastic: > Virgin Polyethylene Terephthalate (PET)

+ What about the materials, do you think you will use different materials than PET?

"To incorporate PCR PET / HDPE in our packaging: Post-consumer resin (PCR) plastic is the recycled materials from existing PET bottles and other plastics. HDEP is the easiest plastic polymers to recycle."

+ What is the bigger constraint for the business, what is the main challenge? Why? How did the company try to solve it? When did an innovation occur?

"To help mold consumer's behavior so that disposing to recycle becomes an engraved habit in everyone's daily routines."

Opening Questions (10 MIN.)

+ I would like to better understand how the company started to actuate in a decentralized business model? Do you imagine that changing?

"We were the first company to introduce *hole-in-the-wall* in Europe. We install production units within the customers' factories in partnership. Only the preforms are transported, reducing shipping costs. (1976)"

"We launched the 29/25 bottle neck, which allowed for a 20% weight reduction – this has become a worldwide reference." (2005)

"Add answer here…"

Interview Documentation (2)

"Supporting draw…"

Design and Innovation (handling the prototype) (30 MIN.)

30.09.2019	Cascais, Portugal

Design and value creation	Process and operations	Partners and network	Craving to innovate	Perception / expectations	Reflection
"Wise pack is not interesting to our company because the reusable packaging goes against our business model so it is something that our company does not defend." "The shelf is very important for your clients, is the contact with the end-user. Wisepack don't allow much differentiation." "launched the Vitalis water bottle, the first rigid plastic packaging (…) the bottle uses less raw material." "Support Ecover launch the first worldwide bottle made with 10% ocean waste plastic + Post-consumer resin (PCR) plastic is the recycled materials from existing PET bottles and other plastics." (2014)	"The *hole-in-the-wall* introduction in Europe, reducing shipping cost." (1976) "We launched the 29/25 bottle neck: 20% weight reduction and a worldwide reference." (2005) "To incorporate PCR PET / HDPE in our packaging." (2025)	"Engaging with key actors in the supply chain to develop, evaluate and validate new and/or alternative raw materials and recycling technologies." "Working together with our Customers to incorporate recycled raw materials in their products in a correct and balanced way."	(2025) "We will strive to promote recycling streams so there is enough recycled raw material to reduce the consumption of natural resources. And we will help mold consumer's behavior so that disposing to recycle becomes an engraved habit in everyone's daily routines." "Implementing lightweight/"rightweight" programs"	"To support the implementation of Deposit Return Systems (DRS) for single-use plastic drinks bottles in the countries where we operate." "Designing and producing reusable packaging, when applicable." "Reduce GHG Emissions and Operational Waste across all the plants." "Continue to promote a conscious and efficient use of Water."	

Interview Documentation (3)

Ideas (5 MIN.)

"Add answer here…"

Sustainable strategy:
Global Commitment to eliminate plastic pollution at the source.

The company is among the first members to sign the Global Commitment alongside Danone, H&M group, L'Oréal, Mars Incorporated, PepsiCo, The CocaCola Company, and Unilever. This first group of companies represents 20% of all plastic packaging produced worldwide.

Conclusion (5 MIN.)

Business model:
"Wise pack is not interesting to our company because the reusable packaging goes against our business model so it is something that our company does not defend." Nevertheless, the company has in the goals for 2015, "Designing and producing reusable packaging."

Take-Back loops:
The company support the implementation of Deposit Return Systems

Attract attention and seduce the user:
"The shelf is very important for your clients, is the contact with the end-user. Wisepack don't allow much differentiation."

Emissions (transport included):
"Reduce GHG Emissions and Operational Waste across all the plants."

"Supporting draw…"

EPAL
Drink tap water

Ecover plastic from the Oceans

Vimagua
reusable, eco-friendly, 100% recyclable and lightweight water bottle

APPENDIX C - Interview synopsis: productor of goods/filler (I6; I7; I8; I9)

Interview Documentation (1)

"Supporting draw..."

Introduction (5 MIN.)

[redacted], Brussels, Belgium	Org. Type: Goods producer (filler)
[redacted], Senior Strategic Innovation Manager	24.07.2019 / 10.02.2020

Get to know (5 MIN.)

+ Working with cross multi-functional teams
+ Consumer centric innovation model. Open innovation management, legal frameworks for collaboration, IP strategy, Technical Due Diligence for Manufacturing & Assembling and Stakeholder Communication.
+ HomeCare categories (due to the large size of the company, it was required to identify one area aligned to this research, to identify the person: HomeCare was suggested)

+ Which materials are more often use in HomeCare packaging? Do you think you will use different materials in the future?

"It depends, PET is the most used because of the light weight. HDPE, the costs is lower, but HDPE is more difficult to recycle."
"Replacing the material is something that we are always open to. But usually is a suggestion form the supplier. We analyse, test and eventually change."

"You mean recycling material? Up to now those solutions came from the packaging manufacturer partner. What drives us is is the costumer, so the aesthetic and safety are very important."

Opening Questions (30 MIN.)

+ I would like to better understand if the company actuate in a centralized or decentralized business model? Do you imagine that changing in the future?

"Depending on the product and the country where the plant is located, both packaging business models are used."

"Why not?! The user is very influential and the company have a strong consumer centric approach. The consumer always decide. The shelf is the most important decision moment and impacts all the decisions along the supply chain."

"Add answer here..."

Interview Documentation (2)

"Supporting draw..."

Design and Innovation (handling the prototype) (30 MIN.)

24.07.2019 / 10.02.2020	Brussels, Belgium

Design and value creation	Process and operations	Partners and network	Craving to innovate	Perception / expectations	Reflection
" I would focus on +3 liters bottles as you'll avoid pet competition." " (+3 liters) the problem of volume during shipping increases." "This creates also an up opportunity; as the concept plus a handle would be novel."	"we identify big consumer problems that aren't being met today and look for business and technology partners to help solve them. Then, we use our resources and expertise to develop, test and refine the brands to set them up for long-term success. Finally, we help the new brands scale and grow into their full potential."	"Working with [redacted] and [redacted] teams on the recycled beach project was amazing, but it is a tough challenge. " "The main lesson from this (recycled beach) project is that cooperation between stakeholders is key." "We overcame this challenge because [redacted] worked closely together along the plastic value chain, from collection to treatment and transformation, but also right through to marketing."	"1 model shampoo bottles with 25% recycled beach plastic. Usage of 50% rHDPE." "A unique and disruptive approach that enables us to accelerate and elevate our product research and development processes."	"The customer valorize environment less than product lower costs."	"Cooperation between stakeholders is key." "Worked closely together along the plastic value chain."

Interview Documentation (3)

Ideas (5 MIN.)

+ B2B markets – Hospitals
+ > 3 liters packaging
+ Use the existent distribution channels to collect after use

"Add answer here..."

Conclusion (5 MIN.)

This innovation should be proposed by a manufacturer that is already suppliers of the company.

This would be an advantage for Home Care like suffice care; laundry; or B2B for example Hospitals (it is easy to collect).

A goods producer have interest in the story to tell the users: "Oceans related"; "CO2 related with transportation (filled)".

User is a group very influential:
Reuse depending on retail "Never works". Developing collecting systems and ecosystems to support refill is interesting. B2B can facilitate de go-to-market, may be a pilot.

"Supporting simulation. By Wisepack."

Comments

Add your comments here...

APPENDIX D - Interview synopsis: retailers (I10; I11; I12; I13)

Interview Documentation (1)

"Supporting draw..."

Introduction (5 MIN.)

[redacted], Porto, Portugal	Org. Type: Retailer
[redacted], Chief Scientific Officer	13.12.2019 / 15.01.2020

Get to know (5 MIN.)

(translated from Portuguese)

+ The chain comprises hypermarkets of 2 000 m2 in medium-sized urban centers, very strong in the consumer goods, namely food.
+ Large Distribution Business (Hypermarkets), average store area: 9 000 m²
+ Articles: about 70 000, in the food, perishable, light bazaar and textile segments.

+ Which materials are more often use in HomeCare packaging? Do you think you will use different materials in the future?

"The company has sought to reduce, recycle and reuse or pack its own brand plastic packaging, anticipating until 2025 the Sustainable Development Goals established by the United Nations until 2030."

Opening Questions (10 MIN.)

+ I would like to better understand the company attitude and values towards sustainability and circular business models?

"Encourage and value national production and promote sustainable consumption."

"Working on the eco-design of your products and looking for the best solutions - credible from a functional and environmental performance point of view and acceptable from an economic point of view. We do this through constant market research, contact with different stakeholders and through Research and Development projects."

"Add answer here..."

Interview Documentation (2)

"Supporting draw..."

Design and Innovation (handling the prototype) (20 MIN.)

13.12.2019 / 15.01.2020	Porto, Portugal

Design and value creation	Process and operations	Partners and network	Craving to innovate	Perception / expectations	Reflection
"Food waste is important for the company and we are looking to solutions." "If we can reduce the waste at our stores close to zero. We would do it." "Working on the eco-design of your products and looking for the best solutions: credible from a functional and environmental performance point of view and acceptable from an economic point of view. We do this through constant market research, contact with different stakeholders and through Research and Development projects."	"Anticipating what the future may bring, such as understanding the client's needs and preferences, followed by a moment of experimentation and a learning approach that culminates in the implementation phase."	"Promoting regional employment and strengthens the competitiveness of national suppliers" "Promoting a stronger relationship between producers and academia and research centers."	e.g. Food: + 6 Projects developed; + 224 Members; + 248 million euros in purchases; + 4.5 tons of fruit and/or vegetables distributed every weekend, to children who visit our stores; + 114 thousand tons in purchases. + "(...) products made from the surplus of a retail chain. (...) made from end-of-life food products from our stores in order to combat food waste, namely tomatoes, squash, peppers and onions."	"The company has sought to reduce, recycle and reuse or pack its own brand plastic packaging, anticipating until 2025 the Sustainable Development Goals established by the United Nations until 2030."	+ To reduce the waste at the stores - *close to zero goal* + to reduce, recycle and reuse or pack its own brand plastic packaging + *5 strategic pillars:* + *Energy and Climate Change* + *Circular Economy* + *Responsible Sourcing* + *Responsible Offer* + *Communication, Awareness and Education*

Interview Documentation (3)

Ideas (5 MIN.)

"To transform the daily food waste into energy locally and inject the energy produced in the store's consumption."

"Add answer here..."

Conclusion (5 MIN.)

"Responsible use of plastic. To reduce, recycle and reuse or pack its own brand plastic packaging."

"Dissemination initiatives to minimize the impact of the continent's ecological footprint, with greater responsibility as a retailer."

"Close relationships with customers, suppliers and employees, the brand also has a duty to inform the community about what we can, after all, change together."

"Promoting a stronger relationship between producers and academia and research centers."

"Supporting simulation. By Wisepack."

Comments

Add your comments here...

APPENDIX E - Interview synopsis: recycling park (I14)

Interview Documentation (1)

"Supporting draw..."

Introduction (5 MIN.)

[redacted], Ghent, Belgium	Org. Type: Recycling Park
[redacted], Director of Operations	14.08.2019

Get to know (5 MIN.)

+ We collect and compress waste from the urban areas and it is storage per category here in the park. The less volume the waste arrive better we can optimize de process.
+ It is transported to material-processors companies: shredded, crushed and the plastics are granulated in small pieces
+ It is transported to several specialized material-processors to be recycled and sold
+ The sorting starts happening at:
  + Citizens houses
  + Retail park and material-processors: to recycling; landfilling; or energy recovery and fuel derived from waste
+ It is sorted and processed to be reintroduce in new manufacturing processes
+ All ecosystems work differently, it depends on the local stakeholders and material

+ Which materials are more often collected at the recycling park and sold here? Do you think other materials will create profit in the future?

"Currently, polystyrene (EPS) from home-appliance packaging is sold here to a local company. But the returns are not significant. We also have a large volume of mattresses and used appliances, but the revenues are not significant. It is not faced as a business to create a return."

"I don't think this will change. Maybe new recycling parks will be developed already with the circularity as base concept. Or the law change, such the one for flexible plastics from last year."

Opening Questions (10 MIN.)

+ I would like to better understand the company attitude and values towards circular economy?

"Collection from residences are about 90% and the remaining 10% is urban industries (e.g. restaurants)."

"Demolitions materials is processed by private companies, so it is not included in our data."

"As long as the quality of waste separation depends on the user, the circular economy will be compromised. We cannot expect the user to learn how to separate all types of materials. Otherwise, the use of new materials is also limited. The collecting system itself and all the value chain have to become more autonomous, more intelligent. "

"Add answer here..."

Interview Documentation (2)

"Supporting draw..."

Design and Innovation (handling the prototype) (30 MIN.)

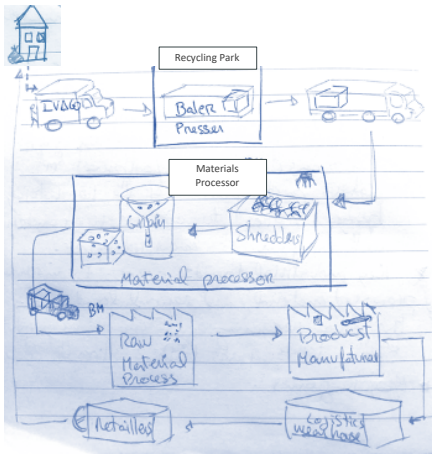
14.08.2019	Ghent, Belgium

Design and value creation	Process and operations	Partners and network	Craving to innovate	Perception / expectations	Reflection
"The package arrive broken and the plastic bottles already deformed. WisePack will not be exception." "We can not have labour separating this kind of bottles!" "Special containers like the oil from restaurants? But different brand are collected in the same container... I don't see future in it!" "It needs to be separated, granulates and then you can reuse the recycled material. That is the only was"	"We can not have labour separating this kind of bottles!" "Special containers like the oil from restaurants? But different brand are collected in the same container... I don't see future in it!" "It needs to be separated, granulates and then you can reuse the recycled material. That is the only was"	"I don't know what the others do (with the waste). We receive it, place it in separate areas to be collected again." "The next step the waste is processed for example, granulated (if plastics) or pressed (if cardboard and paper). This process is just to reduce the volume during transport to several other processing companies more specialized. Only after is transformed§ in recycled materials."	"There is no innovation here! This is just waste!"	"This is just waste!"	+ Negative connotation of waste + The Business model focus on services and it does not include selling the waste as a resources + The waste is submitted to taxation based on weight or volume. It is not faced as a valuable resource.

Interview Documentation (3)

Ideas (5 MIN.)

Add your comments here...



Conclusion (5 MIN.)

"Waste is not valorized and has a negative connotation for employees. Social value and a sense of mission are what make workers proud."

"The is no value proposition for the resources (only for the service and land)."

"The waste is submitted to taxation based on weight or volume. It is not faced as a valuable resource."

"The innovation culture is not transmitted to the operations workers (eventhood the company participates in several innovative initiatives)"

"Network informal but distant. Lack of knowledge of the supply chain and network"

Comments

Add your comments here...

APPENDIX F - Interview synopsis: industrial association (I15; I16; I17)

Interview Documentation (1)

"Supporting draw..."

Introduction (5 MIN.)

[redacted], Brussels, Belgium	07.11.2019
[redacted], Business Group Leader Manuf. Plastics	Industrial Federation

Get to know (5 MIN.)

+ (IF) The 1 700 members (300 000 workers) are companies which seek to contribute to the world's advancement by developing innovations through technology
+ (IF) Several federations in Belgium requested a study related to the use of plastic in the current context and given the environmental challenges related to its use
+ (IF) The study focuses on the main challenge facing society today, post-consumer waste.

+ Will plastic applications decrease? Its manufacturing and it use? Do you think other materials will substitute the plastic?

(IF) "Since the '50s the number of plastics and their number of applications has constantly increased. Plastics materials are an integral part of modern life."

Opening Questions (10 MIN.)

+ I would like to better understand the company's attitude and values towards a circular economy?

(IF) "The companies are curious. They know that it's a transformation that needs to happen, but they still searching for the best practices recommended starting to implement strategies."

"Add answer here..."

Interview Documentation (2)

"Supporting draw..."

Design and Innovation (handling the prototype) (30 MIN.)

(AE) Academic Expert
(IF) Industrial Federation

07.11.2019	Brussels, Belgium

Design and value creation	Process and operations	Partners and network	Craving to innovate	Perception / expectations	Reflection
(IF) "This could be interesting for reuse. But the collection process would damage it..." (IF) "And the citizens, need to have another recycling bag at home? That can be a problem!" (IF) "it seams complicated to produce..."	(IF) "I think the collection process would damage the package and we couldn't fill it again." (IF) "Collected in store, like the clothes from H&M? That could work!"	(IF) "Well, for this package the material supplier needs to provide something flexible; the mold maker is also an important partner, but I imagine not critical...the collector during the take-back is crucial. And the consumer." ."	(IF) "It could use new materials, with sensors monitoring"	(IF) "The companies are very open to the transition for circularity. But their nature if focus on economic benefits and not environmental."	+ Could be reused + Damage during collecting could be a problem + Sorting separately from the other packaging at domestic level is very unlikely + Raw material suppliers and collecting partners are key-partners + Consumer motivation for take-back can be a challenge + Take-back system should consider an incentive to the user + IoT technologies can support the product-service design + The industry in open to circularity, believes that will have a role in it, but has some have some economical reserves

Interview Documentation (3)

Ideas (5 MIN.)

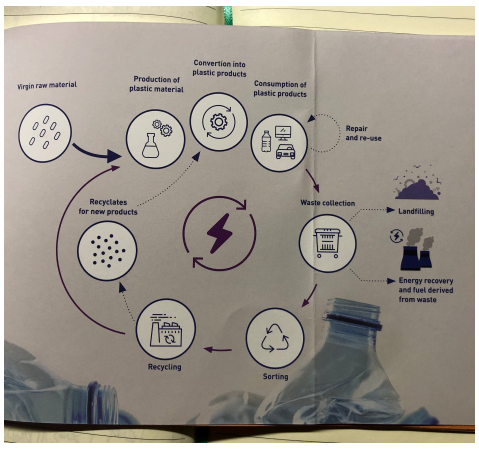
(IF) "It could use new materials, with sensors monitoring."
(IF) "IoT technologies can support the product-service design."

Conclusion (5 MIN.)

+ Could be reused
+ Damage during collecting could be a problem
+ Sorting separately from the other packaging at domestic level is very unlikely
+ Raw material suppliers and collecting partners are key-partners
+ Consumer motivation for take-back can be a challenge
+ The industry in open to circularity, believes that will have a role in it, but has some have some economical reserves

Comments

Add your comments here...



APPENDIX G - Interview synopsis: academic expert (I18; I19)

Interview Documentation (1)

"Supporting draw..."

Introduction (5 MIN.)

[redacted], Brussels, Belgium	07.11.2019
[redacted], Ass. Prof. Circularity Plastics	Org. Type: Academic Expert (AE)

Get to know (5 MIN.)

+ Will plastic applications decrease? Its manufacturing and it use? Do you think other materials will substitute the plastic?

(AE) "Their lightweight and resistance help to address environmental challenges."
(AE) "Plastic packaging prolong the shelf-life of food products and avoid food waste, improves our quality of like and in the automotive industry reduced drastically the fuel consumption (lightweight parts)."
(AE) "To substitute plastic by metals, glass or paper packaging is not the best environmental solution."
(AE) "If human behaviour do not change, bamboo objects will also end up in the oceans."

Opening Questions (10 MIN.)

+ I would like to better understand the company's attitude and values towards a circular economy?

(AE) "Plastic sector is a young sector and is felling the impacts of the environmental crisis that our societies are living."

(AE) "It is a young and dynamic industry, conscient that plastic is a fundamental resource for the circular economy."

"Add answer here..."

Interview Documentation (2)

"Supporting draw..."

Design and Innovation (handling the prototype) (10 MIN.)

(AE) Academic Expert
(IF) Industrial Federation

07.11.2019	Brussels, Belgium

Design and value creation	Process and operations	Partners and network	Craving to innovate	Perception / expectations	Reflection
	(AE) "The take-back process also has environmental impacts. Each case needs to be decided based on a LCA."	(AE) "Its is difficult to motivate take back. Needs monetary incentive, as in glass bottles return on the supermarket."		(AE) "The laws impositions will probably change that, but also regimentations, like standard and policy is still to be developed."	+ Could be reused + Damage during collecting could be a problem + Sorting separately from the other packaging at domestic level is very unlikely + Raw material suppliers and collecting partners are key-partners + Consumer motivation for take-back can be a challenge + Take-back system should consider an incentive to the user + IoT technologies can support the product-service design + The industry in open to circularity, believes that will have a role in it, but has some have some economical reserves

Interview Documentation (3)

Ideas (5 MIN.)

(AE) "Take-back system should consider an incentive to the user."
(AE) "IoT technologies can support the product-service design."

Conclusion (5 MIN.)

+ Could be reused
+ Damage during collecting could be a problem
+ Sorting separately from the other packaging at domestic level is very unlikely
+ Raw material suppliers and collecting partners are key-partners
+ Consumer motivation for take-back can be a challenge
+ The industry in open to circularity, believes that will have a role in it, but has some have some economical reserves

Comments

Add your comments here...

APPENDIX H - Interview synopsis: academic expert/ LCA (I20)

Interview Documentation (1)

"Supporting draw..."

Introduction (5 MIN.)

[redacted], Ghent, Belgium	27.11.2019
[redacted], LCA Researcher	Org. Type: Academic Expert (AE)

Get to know (5 MIN.)

+ Will plastic applications decrease? Its manufacturing and it use? Do you think other materials will substitute the plastic?

"LCA should be set aside at this stage. Due to the recognition that the reduction in volume during transport and the prolongation of the circulation time of each package, are advantage known and accepted by all the stakeholders."

Opening Questions (10 MIN.)

+ I would like to better understand the company's attitude and values towards a circular economy?	"Add answer here..."

Interview Documentation (2)

"Supporting draw..."

Design and Innovation (handling the prototype) (30 MIN.)

27.11.2019	Ghent, Belgium

(AE) Academic Expert
(IF) Industrial Federation

Design and value creation	Process and operations	Partners and network	Craving to innovate	Perception / expectations	Reflection
	"The take-back process also has environmental impacts. Each case needs to be decided based on a LCA."	"New and better solutions to calculate a combined LCA where the components of a product have different lives after all the cycles of use" "The concept of end of life has an end with the circular approach"	"New software LCA" "AI supporting big data and IoT"	"new materials will became part of the LCA"	+ LCA should be set aside of all circular products in several stages. + volume reduction during transport and the prolongation of the circulation time of each package, are advantage known and accepted by all the stakeholders.

Interview Documentation (3)

Ideas (5 MIN.)

"New software LCA"
"AI supporting big data and IoT"

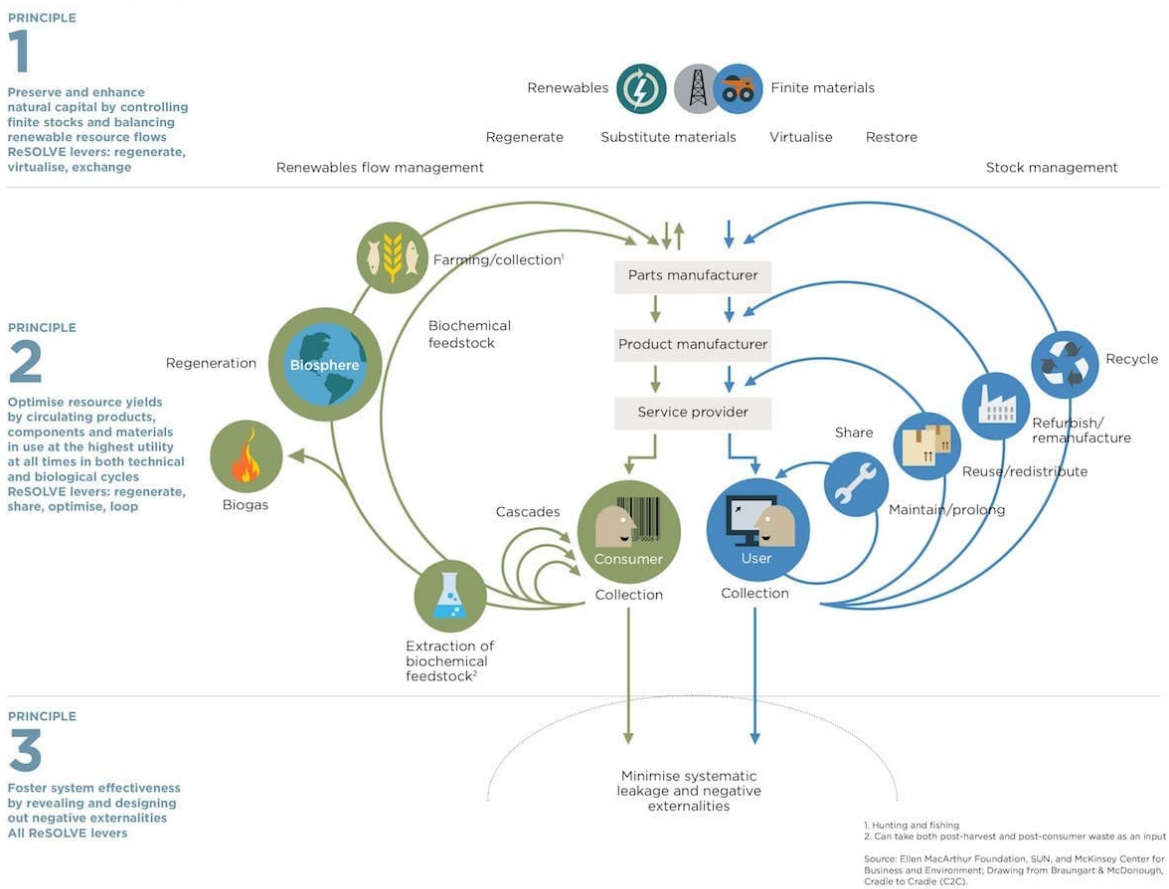
Conclusion (5 MIN.)

+ The concept of end of life has an end with the circular approach.

Comments

Add your comments here...

ANNEX 1 – Outline of a Circular Economy



Source: (*Circular Economy System Diagram*, n.d.)