Circular Design Toolkit for Sustainable Futures

A quick guide for responsible product design

by: M. Alejandra Farías Fornés

Submitted to OCAD University in partial fulfillment of the requirements for the degree of Master of Design in Strategic Foresight and Innovation

Toronto, Ontario, Canada

May 2022

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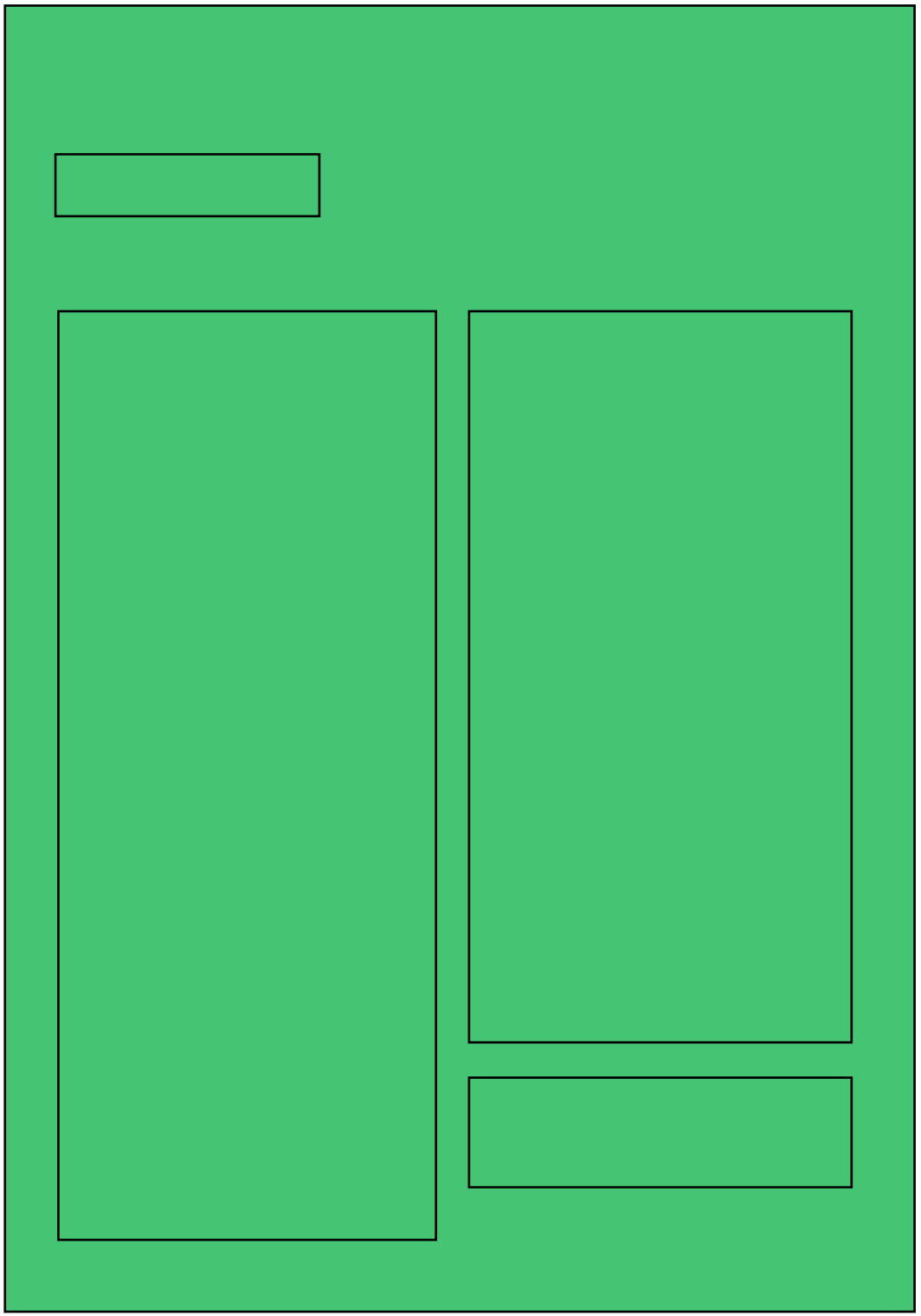

Abstract

The major contribution of consumerism and unsustainable mass production in the environmental crisis has been continuously debated over the years. Although there have been global agreements to cut environmental impact from companies, such as the 2030 Sustainable Development Goals, the pace of policy and regulation has been slow. Meanwhile, the depletion of natural resources and the ability of manufacturing companies to sustainably meet market demand has been exceeded. To prevent irreparable damage and regain a healthy balance with the environment, researchers have pointed to a circular economy model, where products and materials are kept in circulation instead of going to waste. Considering the large impact of these industries, recent studies have looked at the early stages of product design for potential solutions, developing different theories, models and frameworks based in principles of a circular economy. However, few of these methods have been adopted, which is why this research aims to answer the question “how might we encourage designers to embrace circular design practices?”. Believing designers play a fundamental role in the conceptual development of product that will become mass produced, it is necessary to provide designers with the tools and principles of sustainable design. Through a collection of research methods, including literature review, expert interviews and analysis of existing frameworks, this Major Research Project provides a conceptual toolkit for circular design that understands existing design process boundaries and can integrate circular strategies and decision-making tools that can be easily implemented by designers regardless of their knowledge around this topic.

Keywords: *Circular design, circular economy, sustainable futures, industrial design, design thinking, toolkit.*

Acknowledgements

This project would not have been possible without the constant support of my family, not only through this research, but also on my academic journey in a different country to venture into fields outside of everything I know. Thank you for your patience, words of encouragement and always believing in me.

I am also deeply grateful to my primary advisor, who constantly pushed me to go beyond my goals and scope, always providing valuable advice and perspectives, but allowing the freedom to explore this topic according to my vision.

Special thanks to my classmate and friend Justine, for being my accountability partner in this Major Research Project journey, sharing my international confusion in a foreign country, academic frustrations and enduring my chaotic monologues.

Finally, many thanks to everyone who agreed to be interviewed for this research and shared their thoughts and experiences, to my friends who supported me on this journey, to those who provided feedback when I was feeling stuck, and to my cat, Chica, for staying up with me during countless evenings.

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Introduction

The increasing visibility of the present environmental crisis has encouraged society and international organizations to speak up and demand concrete action from the public and private sector on critical environmental issues. Unfortunately, due to varying priorities, the environmental agenda of government bodies has been arguably passive in requiring major companies to reduce their environmental impact and take greater responsibility throughout their products' life cycle. Although there are global agreements such as the Sustainable Development Goals (SDGs) in place calling for action to achieve a better, more sustainable future, the system of mass production to meet increasing consumer demand in a capitalist society has led to the overconsumption of natural resources and the ability of most manufacturing processes to adapt has been exceeded.

To prevent irreparable damage and regain a healthy balance with our environment, literature recommends a move towards a circular economy. This why this study focuses on circular design. According to the Ellen McArthur Foundation, the circular economy seeks to gradually decouple economic activity from the consumption of finite resources, keeping products and materials in use and eliminating the concept of garbage and pollution from the system (Ellen MacArthur Foundation, 2017).

Although the Circular Economy may not be a new concept, as it was first coined in The Economics of Natural Resources (Kneese, 1988), and there is extensive research on the subject, it has not yet been adopted widely by the manufacturing industry. Still, the concept has continued to grow, and **circular design** is described as "designing out the waste and pollution" of the product creation process.

While most things today are designed on a linear model of make-use-dispose, there is a need to redesign these processes based on principles of circularity.

To better understand the problem, it is necessary to highlight what the current situation looks like and what are the factors that are highlighting the need for a circular economy, with the focus on consumerism and the current climate crisis. As the linear economic lifestyle tends to ignore the post-use of consumer goods, a climate emergency has ensued after landfill and sea pollution have dramatically increased, pointing at the vicious cycle of mass production and careless disposal of products as a big contributor. And although the SDGs proposed international agreements to counteract the major social and environmental problems by 2030, the critical situation calls for more holistic and immediate approaches.

As many studies and organizations cited throughout this research suggest a circular economy strategy to address the problem, several theories, frameworks, and strategies have been created centering on the design and production of consumer goods, which has provided the groundwork for this project.

Research Questions

Before trying to propose solutions, it was aimed to better understand the problem and its implications, formulating a series of research questions to help develop potential solutions or strategies. The most relevant question was **"How might we encourage designers to embrace circular design practices?"**. Beginning with the idea that designers have an important role in the conceptual development of product that will potentially become goods of mass production, a circular economy philosophy should be cultivated in the industry. This would require the unpacking of the related basic

principles of sustainable design, making them easier to understand, and promote their adoption.

A supporting question was **"How might we make environmental sustainability more intuitive to supporting stakeholders in the development process?"**, being aware that product development processes involve various departments and actors that could be driving decisions in terms of materials and processes.

Finally, questioning **"How might we give designers the autonomy to make decisions regarding product design to favor or achieve a circular economy?"** lead to explore the decision-making power of designers, and whether the power should fall to them.

> "How might we encourage designers to embrace circular design practices?"

Methodology

The first stage of this research was centered around a literature review, exploring current principles and existing approaches to Circular Economy and design. This included unpacking typical industrial design processes from various products to determine who is driving which decisions, and how they defined the parameters and barriers faced in the process that are ultimately impacting the physical outputs that could potentially harm the environment.

Research about the relationship between circular economy and design were further analyzed, as examples of conceptual tools created from collective literature on the subject set the baseline for developing new approaches and pathways to circular design.

Following this secondary research, a set of semi-structured interviews with experts in domains related to design and manufacturing provided a better awareness on current practices and approaches to sustainability from various fields.

Additionally, an affinity mapping was conducted from the interview responses to find recurrent themes and topics, helping to develop potential interventions to address barriers to sustainable design within the product development process.

After gathering insights from the previous stages, a comparing analysis of frameworks related to circular economy and design, revealed common patterns and gaps that presented potential opportunities to explore. Afterward, an assessment of how these concepts, tools and trends could assist and improve the current system of product creation offered a path to design a new design toolkit.

Finally, based on the collection of findings of the research, interview insights, and framework assessment, a conceptual toolkit was developed to help integrate circular strategies to a typical design process. A short explanation of each tool module and how to use it was included, followed by a series of recommendations and closing remarks on the conclusion of this research project.

Product Development Process

Consumer products, whether tangible or intangible, involve a complex process to reach the market place. The process of creating products regularly follows a flow of activities that start with abstract ideas or concepts and progress through a series of processes that include prototyping, testing and production. The goal is to create a product that addresses the needs of the user and generates revenue to the company, while responding to market changes, and consumer needs.

Figure 1: *New Product Development (NPD) process model (Cooper, 1993)*

Most product developing companies use a model or framework with five to eight stages, although they all perform essentially the same activities. A traditional, five-stage ew Product Development (NPD) model will be used to roughly describe the activities required to create a product within an organization.

It is important to highlight that not all companies follow every step of the process, nor in the specified order, as this depends on the company preference and available resources.

A traditional NPD model (Figure 1) contains the following stages:

Idea Generation

The first stage of this process involves the generation of many new, diverse product ideas in a divergent process, where the more ideas generated, the better. These are searched internally, that is, within the company, through workshops, brainstorming, R&D activities, etc. or externally, through market research, Focus Groups, or hiring marketing agencies or consultants.

Screening

The second stage aims to filter these ideas based on criteria determined by the company. These can be viability, desirability, cost, etc. The goal is to end up with ideas that have the potential to be profitable within the previous group. Other activities of this stage may include analyzing the market to confirm that the product does not exist or come up with a better product that can confidently outperform the competition.

Concept Development

The next step is to take promising ideas and expand them into product concepts, which is a detailed vision of the product, analyzing potential costs and specific features. It is also important to evaluate and compare the concepts through a SWOT analysis or other frameworks to evaluate areas of improvement. Ideally, these concepts are presented to potential consumers to assess the product's desirability and the consumers' purchasing intent. These activities allow the discarding of less successful ideas to concentrate efforts on the most solid concepts, shaping them into sketches and 2D drawings.

Product Development

The next step involves taking one of these champion ideas through the design process, which is a flow of specific activities focused on refining the final form and function of the product. Here, the preliminary design is transformed from 2D into 3D with CAD modelling, followed by rough or advanced prototypes that can be used for Market Testing. Based on the results and evaluation of engineering, marketing and other relevant areas, it is decided whether the prototype progresses to a large-scale production, with the creation of the final design and its subsequent manufacturing.

Commercialization

Once it is decided to launch the

product, the strategy is refined to introduce it to the market, aligning all the areas of marketing, sales, and distribution to ensure a successful campaign. Although this stage includes a monitoring of the product's reception, to provide optimal customer service, this is where the product development process usually ends.

Design Thinking

Although the NPD process shown and comparable models are often used for large scale product innovation, it is a highly technical and arguably linear process. A slightly different approach is Design Thinking, an iterative process commonly used in design-driven companies by which design research and methods are employed to match people's needs with what is technically feasible and a viable business strategy (Brown, 2008). Design Thinking is used globally by designers and non-designers to create human-centered products, services, and businesses.

Although there are also variations of Design Thinking, one of the most well-known models also consists of 5 stages, some similar to those of the NPD process, although with a larger focus on the ideation process and user experience. It

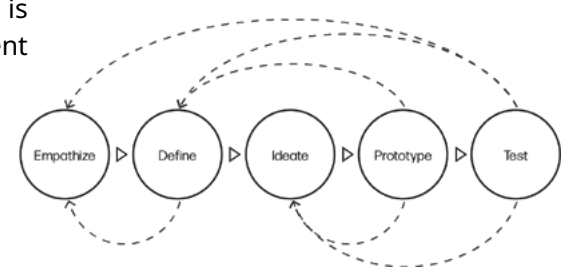


Figure 2: *Stanford Design School Design Thinking model.*

does not directly address the production stage.

This model was developed by Stanford Design School (d.School), now known as the Hasso Plattner Institute of Design. Its stages are as follows:

Empathize

Contrary to the NPD process, this model starts with a challenge, brief or problem, and this step seeks to understand the user experience to discover their deep needs and gather new insights. This stage is about learning and discovery, so it involves primary and secondary research to get a better sense of the problem context to understand different points of view from consumers and other stakeholders.

Define

In this next stage, the information that was obtained is analyzed. By synthesizing the findings, the problem can be perceived differently, developing a point of view that will allow a reframing of the question and open the solution space. During this step, it is common for designers to use Journey Maps (Gibbons, 2018) to highlight overlooked problems or activities in user interactions with the product, which helps to redefine the problem from these perspectives.

Ideate

As the name implies, this stage is similar to the idea generation step in the NPD process but with slight differences. The first part is also exploratory, seeking to generate as many ideas in the shortest possible time. These rough ideas are evaluated, and those considered most promising are developed into more refined concepts and later compared and assessed against specific criteria or metrics. The best concepts are then sketched in more detail.

Prototype

In this stage, CAD models are made and used to create more realistic visuals such as 3D renderings. After some minor adjustments, these can be printed in 3D or used for reference for the creation of rapid prototypes with inexpensive materials. This stage is important to validate shapes and dimensions, ergonomics and give a more tangible idea of the final product, and also allows designers to learn from the prototypes to inspire new ideas.

Test

In this "final" stage, realistic prototypes are used for usability testing. These testings provide insight into the user experience and can help to rework the design from rethinking some of the previous steps. Tests

can provide new ideas, refine the problem statement or uncover new understandings around the initial scope. After a few iterations, the refined concept and 3D models could be carried forward to production stages.

What is missing?

While there are many methodologies for product development, these are usually adapted by each organization's capabilities, resources, and departments, but in general coming close to one of these two approaches, with some important distinctions. The NPD is more strategic and focused on how to produce and launch a product effectively, while Design Thinking seeks to understand the problem thoroughly and ensure that the product or concept responds to real user needs.

The problem with these processes is that they focus on the development and use stages of the product but ignore its post-use or disposal. There are several possible reasons as to why they do not pay attention to these subsequent stages, optimistically, one may believe that they are simply overlooked, as it is beyond their knowledge or control. But this can be attributed to planned obsolescence. This practice refers to the business strategy of deliberately making products with a limited useful life so that the consumer feels the need to buy new products or services that the manufacturer offers as a replacement or upgrade of the old ones (Kramer, 2012). Even assuming this is not the case, they choose to overlook the possibility that the user loses interest in their used product, and more importantly, what happens with it when it reaches the end of their useful life.

Double Diamond

In order to analyze the opportunity areas within these models, a third model also born from the original Design Thinking was considered; the **Double Diamond** process. This methodology was created by the British Design Council in 2005 and has been since updated to provide a model that can be used in most fields (Ball, 2019). in the following image. Figure 3 presents

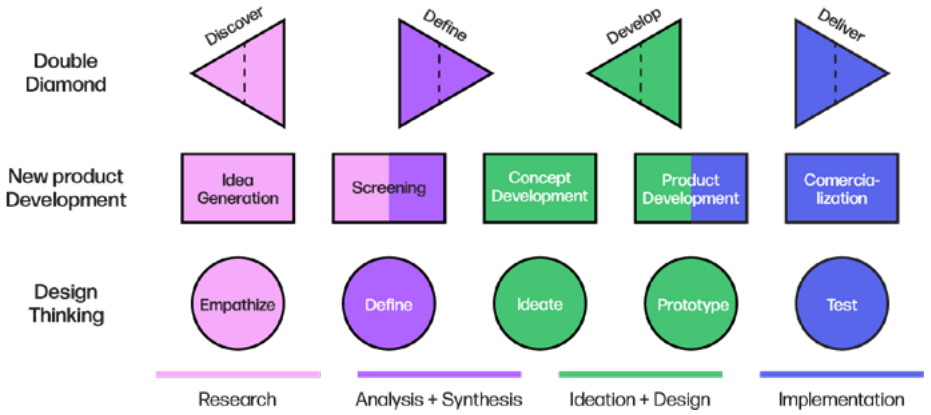


Figure 3: *Double Diamond, NPD and Design Thinking stage comparison.*

a summary comparing the three models, showing overlapping stages and the goal of each stage.

For the purpose of this project, and in order to talk about a methodology that covers both manufacturing and commercialization aspects but is centered on the user, the Double Diamond methodology will be used as a base model to apply the new toolkit.

Starting with this base methodology, the activities and characteristics of the entire process were broken down, identifying the general inputs and outputs along with the key Stakeholders (Table 1) to understand the full flow of activities

Stage	Discover	Define	Develop	Deliver
Intputs	Brief Marketing insights	Data Research	Customer insights Budget restrictions	Raw material Sourced parts Customer feedback
Outputs	Requirements	Findings Insights	Design concepts Sketches 3D prototypes Tech specs	Final product Marketing plan Production waste
Activities	Briefing Primary research Secondary research	Analysis Filter data	Ideation Sketching Evaluation Selection Technical design	Part sourcing Manufacturing Packaging Distribution Marketing acts.
Stakeholders	Management Marketing Design Engineering Customer	Marketing Design Customer	Marketing Design Engineering	Design Manager Project Manager Marketing Sourcing Supplier Retailer

Figure 4: *Methodology breakdown*

carried out, for which a design toolkit would have to be mindful of.

Case Studies

The product development process outlined so far, generalizes the production aspects in a single Launch stage, which covers the process of obtaining materials, its transformation and distribution and commercialization, but not retirement. This series of connections make up the tangible process of creating an object from its raw material, that is, the life cycle of a product. To better exemplify this process, two products will be reviewed as cases through their full cycle. Since the specific process in which these products were produced is unknown, and only the public, available information will be considered, various assumptions will be made, based on a typical process of product development.

Glass tumbler

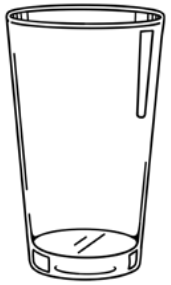
As a first example, a glass tumbler of the American brand "L", sold in the United States but produced in Mexico is used. Glass is known to be highly recyclable, so this is used as an example of a product cycle that - in theory - does not have a major environmental impact, beyond the embedded energy to produce it.

Starting with raw materials, soda-lime glass, which is the most common glass; is a resource-efficient material, since it is made from abundantly available materials including sand and recycled glass. Without going into the detail of the extraction process, these materials go through a furnace to be melted and turned to liquid glass, then into the formation process, in this case, press molding to get the tumbler shape. Then it goes to a quality assessment, where any of the glasses that do not meet specific standards return to the furnace to be melted and remade. The glasses that pass the quality assessment are packed and transferred from the production plant to the point of sale or retailer. In this specific case the plant is in Mexico, so it needs to be shipped to the USA. The final store is the first point of contact with the consumer, who purchases the product and begins the product's cycle of use. Due to the brittleness of the glass, it is likely that it will eventually break, which will provide two ways of disposal for this material. Depending on the user's knowledge and accessibility to a recycling site, it can be either thrown away as garbage and end up in a landfill, or it can be recycled. If it reaches the correct recycling facilities, it will re-enter the process and be melted to become a new product.

Although the product used in this example is quite simple, there are other glass products that can lose their recyclability properties when in contact with other materials, such as decorated or colored glasses. Also, not all types of glass are as easy to recycle, Borosilicate being an example of this. This glass contains an additive that makes it more resistant to impact and temperature changes, which is why it is used for baking trays and coffee makers, but requires a very high temperature to melt.

Additionally, because it is more durable and long-lasting, there is not as much flow of broken glass compared to more common glass supported in the collection and recycling process.

Borosilicate Glass French Press



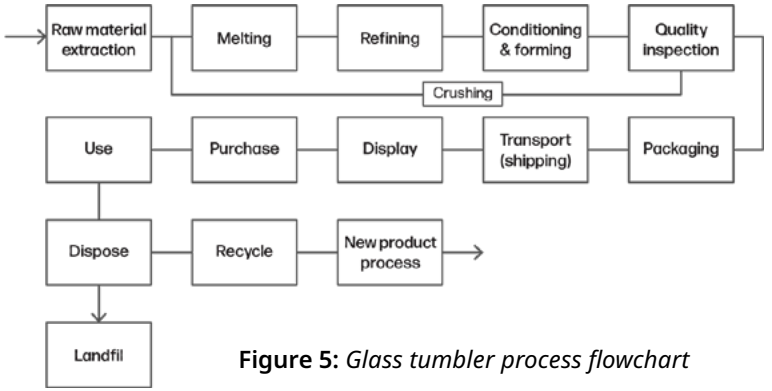


Figure 5: *Glass tumbler process flowchart*

A second example reflecting a hybrid of materials, is the 3-cup French Press. This is made in Portugal, and sold in Canada by the Danish company “B”. This process seems complicated at first glance, but reflects each element’s integrated process.

It can be seen that the product starts from the extraction of natural resources from each material, in this case, the pieces are made of Polypropylene (PP) plastic, Stainless Steel and Borosilicate glass. All of these are processed and transformed into their respective shapes through various processes with different amounts of waste and production emissions. All of these parts are transported and assembled into the final product, packaged and transported to a retailer warehouse for e-commerce and /or international shipping. As the consumer uses the product, it is likely that eventually the glass jar (carafe) breaks and needs replacement. The broken jar will most likely be disposed of in the garbage. While it could be disposed to recycling facilities or containers, but as was mentioned before, this glass is hardly ever recycled due to the many constraints related to its properties, energy requirements and logistics, ultimately ending up in landfill. If a replacement carafe is obtained then the product is given a second life and might continue to be used until a new part is broken, relying on the consumer willingness to replace and part replacement availability.

Although there are some available replacements for this product (Jar, metallic filters etc.), some of them, such as the plastic body, are not available. In the ideal scenario for this product, every part can be separated and recycled but hardly a task that the consumer will do if the disassembly is difficult.

There are methodologies such as the Life Cycle Assessment (What Is Life Cycle Thinking?, 2016) that evaluate the environmental impact associated with all the stages of the life cycle of a commercial product.

From raw material extraction and processing or birth of the product, through to the product’s manufacture, distribution and use, to the recycling or final disposal of the product and materials it is composed of, but as it has been pointed out, it is the intention of this project to create a guide that allows and empowers the designer to make decisions and to choose strategies to manage the product’s life cycle.

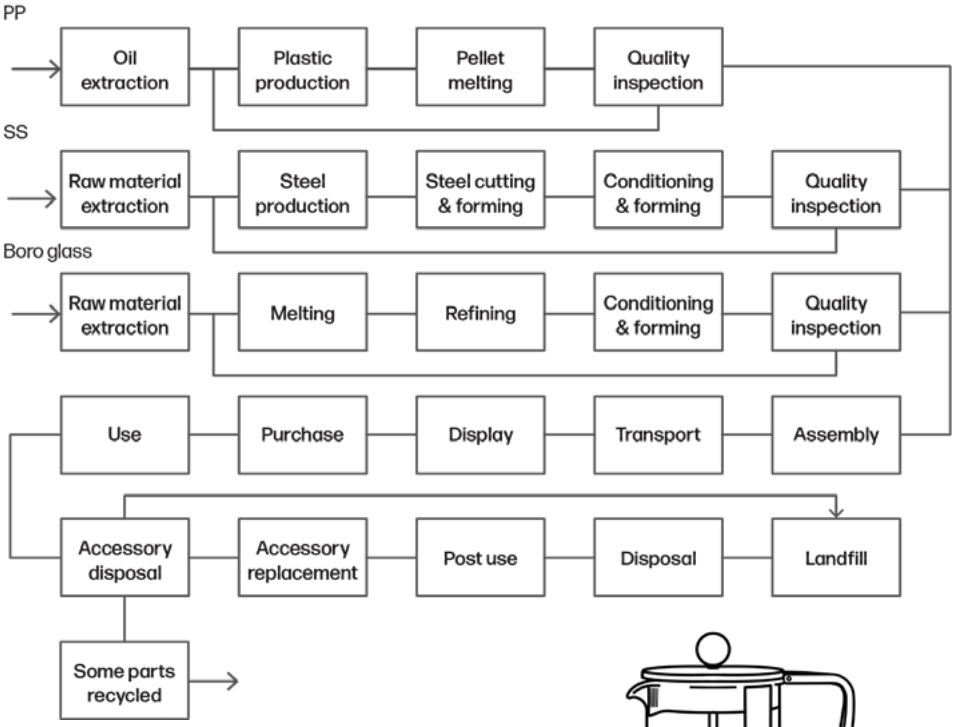


Figure 6: *French press process flowchart*

Opportunity Areas

On a simple exploration, there are many areas of the manufacturing process that can be improved in favor of sustainability, but as the LCA assessment criteria suggests, there are also key points of intervention throughout the entire product's lifecycle that may be overlooked. Depending on the capabilities and interests of the company, it may be oriented towards one or more of the following areas:

1. **Raw material extraction:** Limiting non-renewable material extraction and exploring alternatives such as recycled materials or materials that can naturally return to the environment without any negative environmental implications.
2. **Material processing:** Avoid using materials that lose properties after reprocessing or fuse materials that makes the recovery virtually impossible.

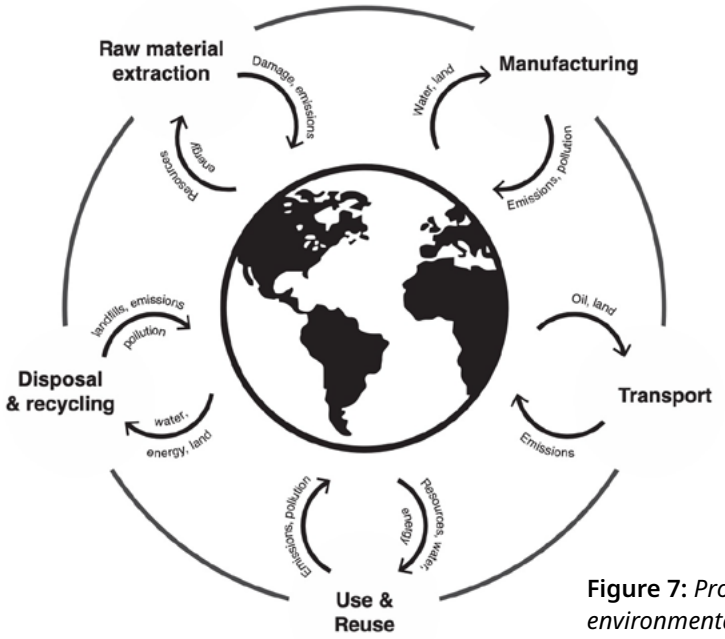


Figure 7: *Product lifecycle environmental flows*

3. **Distribution:** Sourcing materials and products from other countries, contributing to global carbon emissions. Additionally, shipping products requires packaging in disposable materials to secure the product that may be hard to recycle such as plastic film or wax-coated cardboard.
4. **Use:** Ignoring the use stage and post-use of products. If a product receives good care, it can either be reused or passed on, extending its use. Alternatively, it can be taken apart, and recycled or repurposed.
5. **Disposal / End of Life:** Identifying and planning to address the many inputs and outputs of resources, materials, emissions, waste, and pollution, etc. There is a need to map all points of impact beyond production stages and to design for consumer awareness.

The Circular economy and design

In contrast to the manufacturing production cycle with its obvious faults and disintegrated loops to the environment, in the natural world these cycles are continuous. That is, there is minimal concept of waste. The materials flow in such a way that the waste of one organism is food for another, even as one organism dies, it turns into nutrients for another species and feeds the earth again to continue the cycle.

The Circular Economy aims to assimilate this natural model, as the Ellen McArthur Foundation explains, it seeks to gradually decouple economic activity from the consumption of finite resources, keeping products and materials in use and eliminating the concept of garbage and pollution from the system. (Ellen McArthur, nd). In design, this model is extensively explained under the framework of "Cradle to Cradle" or C2C (Braungart & McDonough, 2018), contrasting

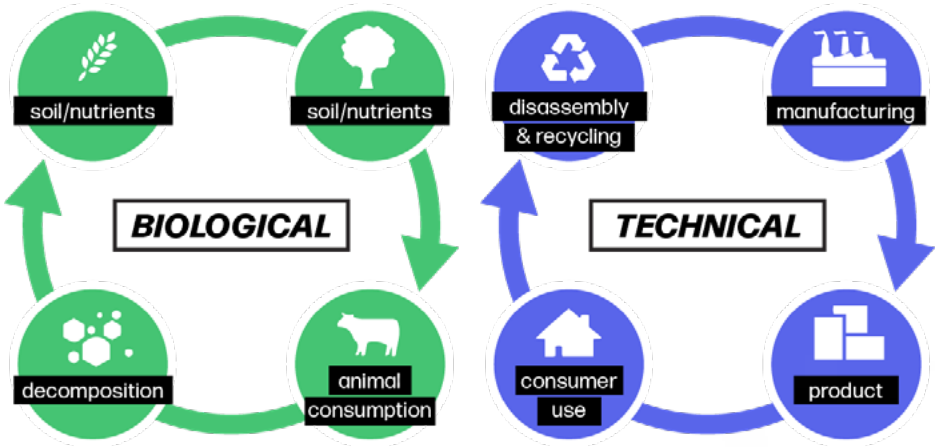


Figure 8: *Biological and Technical cycles*

the traditional industry approach of "cradle to grave" of a product, which follows a linear process, and ends with disposal, whereas the C2C continues the idea of eliminating the concept of waste.

This framework also outlines three principles derived from nature: (1) Everything is a resource for something else, (2) everything can be designed to be disassembled and safely returned to the soil as biological nutrients, or (3) reutilized as materials for new products as technical nutrients. The two nutrient cycles, biological and technical are exemplified in two simplified diagrams in Figure 8.

Circular Design

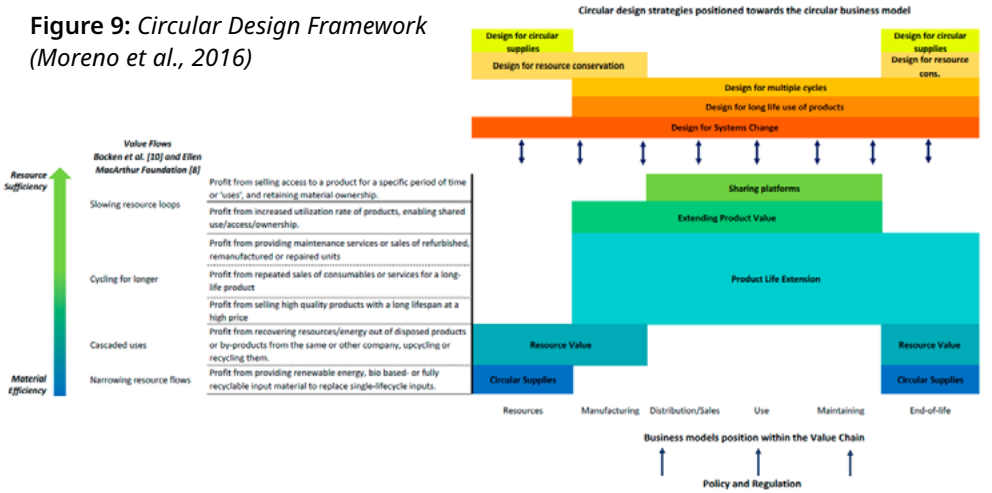
As noted by Moreno et. al. (2016), most literature on the circular economy has focused primarily on the development of business model structures, and, on a smaller scale, on design strategies that go beyond material resource loops and longer product life cycles. This is in line with C2C looking more into a system redesign rather than material recovery and circulation. Moreno et al. also highlighted how these approaches provide little guidance for designers on how to design for circular business models and presents a summary of the most relevant strategies, tools and methods derived from Design for Sustainability (DfX). With this taxonomy revised from the work of Bocken et al.(2013) and De Los Rios and Charnley (2015), a conceptual framework of circular design is presented (Figure 9). The circular strategies listed below are linked to circular business models, based both on academic literature on the CE. These strategies, archetypes and encompassing framework are summarized next, and will be a key asset to further stages of this work. Examples are provided with each one to move from theory to practice.

Circular Design Strategies

The five circular design strategies covered are:

1. **Design for circular supplies**
   This strategy focuses on the biological cycles of waste as nutrients or "waste equals food", where resources are captured and returned to their natural cycle without harming the environment. Examples of this can be found in biodegradable materials that are assimilated into the environment such as disposable

Figure 9: *Circular Design Framework (Moreno et al., 2016)*



cornstarch bags that contain no petroleum, but these would need to be disposed of correctly as cornstarch plastic needs a hot and humid environment, generally not achievable in a home compost but more industrial facilities.

2. **Design for resource conservation**
   This strategy covers both technical and biological cycles and focuses on narrowing resource flows, designing products with the least resources necessary. This refers to both the product and the production process. An example of this strategy in practice are monobloc chairs, which are lightweight polypropylene plastic chairs that are mould-injected in a single piece rather than being assembled.
   These products are usually very resource efficient to make them as inexpensive as possible.

3. **Design for multiple cycles**
   This strategy also deals with both technical and biological cycles, focusing on maintaining the materials in circulation through multiple cycles. The best example of this strategy is the "primary recycling" of products such as aluminum cans, given that this material can be recycled into new products without losing its properties or quality. This compares to certain plastics that are usually reprocessed into lower quality products, although technically still aligned with the strategy.

4. **Design for long life use of products**
   This strategy focuses on technical cycles, extending the usable life of a product and offering services for reuse, repair, maintenance, and upgrade. Other approaches of this strategy include increasing the durability of relationships between products and their users through "emotional durable design" (Chapman, 2012*), and changing product ownership by offering services that can enhance longer product life, known as a sharing system. An example of the later can be seen on "tool libraries", where people are encouraged not to buy tools that they would most likely use only a few times, but instead to "rent" these tools.

5. **Design for systems change**
   This strategy is the most complex, and covers both biological and technical cycles, designing as a whole and between its parts to target problems holistically, as opposed to addressing one aspect at a time to find innovative solutions. Participatory design is an example of this approach, where there is a continuous collaboration involving all stakeholders in a design practice.

Circular business models

Complementing these strategies, the paper summarizes five circular business models archetypes listed by Bocken et al. (2016), among others, that cover both biological and technological cycles. The circular business model archetypes include circular supplies, resource value (recovering the resource value of materials to use in new forms of value), product life extension, extending product value (where manufacturers retain ownership and responsibility, but offer product access at a cost), and sharing platforms (peer-to-peer product sharing and collaborative consumption).

These archetypes are mapped against the circular strategies on top, and to the left, describing their position in the value creation flows, providing more detail on the sources of revenue of each model. While the key value of this framework relies in the integration of many approaches and schools of thought surrounding the circular

economy in relation to product design, there is still a lack of clarity as to how to effectively use this as a tool for circular design in the product development process.

In that vein, although the comparison between strategies and circular business models may be relevant at a management level or to entrepreneurs, considering that the purpose of this project is to develop a guide for designers that can be integrated into an existing design process, it was determined to focus solely on the strategies, which could be implemented at an operational level. It is recognized, however, that the integration of the toolkit resulting from this research with business models is worth exploring further.

Gaps in the Circular Design Framework

During the literature review around Circular Economy and design processes, a number of barriers and areas of opportunity were found, which can be summarized as the following gaps:

- There is a lack of clarity on how to effectively use this as a tool more than a guide of potential paths for circular design in the product development process.
- The role of policy and regulation, although recognized as enabler of circular business models and the implementation of design strategies to be explored in future work, it is not clear what the relevance or implications are in the framework.
- While there are some recommendations listed for designers in the paper following the framework, the connection between the two is not as evident and provides little value for a NPD process.
- There is an opportunity to use the framework as a guide to select and assess strategies based on their implications.

Circular Case studies

In order to understand real life applications of circular design, an exploration will be conducted next on case studies comprising products or services applying successful circular design strategies applied in the industry. To analyze these cases, some criteria to be evaluated are type of strategy are they implementing based on Moreno et. al.'s Circular Design Framework. Some key aspects being highlighted are the Circular Business Models and Circular Design Strategies in place, as well as the material flows to potentially use as a guide in later stages. Additionally, a short overview of their End-of-Life solutions and any potential gaps observed in the process.

Case Study	Value	Business Model	Circular Strategies	Other sustainability approaches	Focus on/ impact	Limitations
Tarkett's carpets	Product + Service	• Circular supplies • Resource value • Extending product value	• Circular supplies • Resource conservation • Multiple cycles • Long life use of prod. • Systems Change	Modularity, GHG emissions reduction, remanufacturing, material innovation	Manufacturing, energy, use, EOL	Maintenance services to increase lifespan of products
Ecopixel furniture	Product	• Multiple cycles • Resource value	• Circular supplies • Resource conservation • Multiple cycles	Recycling, Upcycling	Material extraction	Some of their developed plastics may have recycling limitations (Ex. Trashplast)
Gerrard Street headphones	Product + service	• Product life extension • Extending product value • Sharing platforms	• Multiple cycles • Long life use of products	Modularity, refurbishing and upgrading, brand loyalty, standardization of parts	Use, EOL, customer service,	• Limited to their own design and product. It might be hard to expand to other products. • Customer reviews claimed plastic seemed "cheap" which could negatively affect the experience.
Patagonia worn wear	Product	• Resource value • Product life extension • Resource value	• Multiple cycles • Long life use of products • Systems change	Reuse, recycling, Upcycling, refurbishing, repair, swapping	Use, EOL, sourcing,	High price: Worn Wear limited to US only; their program only takes their own products.
Kartell Bio Componibili	Product	• Circular supplies	• Circular supplies • Long life use of products	Implementing sustainable manufacturing processes, creating emotional attachment, luxury made sustainable	Manufacturing, durability, designer products	Accessibility to their products, EOL strategies,

Table 1: *Case Study Analysis*

Tarkett's Desso carpets

Tarkett is a Cradle to Cradle© certified brand, manufactures carpet mosaics for offices, hospitality and large-scale transportation, as well as other flooring solutions. Their products reflect conscious choices not only for people, taking care of aspects of health and well-being, but also for the planet. These products are durable long-lasting flooring that can easily be recycled upon reaching their end of life (Tarkett: Cradle to cradle© Certified, n.d).

In addition to employing modularity principles that favor efficient use of its products, Tarkett uses only recyclable materials, including their own carpet backing developed in collaboration with companies from drinking water to upcycle chalk, and have implemented a take back program to collect post-consumer carpet flooring, including those from other companies. The carpets are processed using their own recycling facility to separate the yarn and other fibers from the backing, and any non-recyclable materials are used as secondary fuel for the cement industry.

Additionally, Tarkett uses 100% renewable electricity in many of their factories and are committed to reduce their GHG emissions by 2030. Further, the brand intends to transition to a service-based model, leasing out its carpet and taking back the old ones for remanufacturing, creating a fully circular business model (Ellen MacArthur Foundation, n.d).

Key materials employed	Sourcing	End-of-life solutions	Segment/area
Yarn Vinyl Linoleum Rubber Wood Other	Recycled content, upcycling industry waste,	• Recovery of products to upcycle • Recovery of external materials for recycling	Interior design & furniture for home/offices

Table 2: *Tarkett Desso carpets overview of strategies*

Tarkett is a prime example of circular design as it displays all 5 circular strategies in practice:

- Design for circular supplies, by using the waste from other products as nutrients to create new products
- Design for resource conservation, by limiting their use of fossil fuels, preserving natural resources, and continuously working on material innovation and efficiency
- Design for multiple cycles, by using recycled materials and doing their own recycling;
- Design for long life use of products, by creating high quality, durable products and employing tiles which allows to replace only the damaged section instead of the whole flooring
- Design for systems change, by integrating C2C principles across every area and process in the company, from creating green products, reducing waste, using clean energy, recycling, and being mindful and transparent every step of the way.

Ecopixel furniture

Ecopixel is a manufacturing company that collects, separates, and re-transforms thermoplastic waste into new products and plastic sheets. The materials are obtained from different sources and collaborations, using household and industry waste as their main feedstock. These are separated and chipped or transformed into small pellets that are later melted into sheets or moulds.

Their core products beside the material sheets include indoor and outdoor furniture and homewares, but have recently started to use their material as a more sustainable casing option for lighting and speakers, which normally use several different plastics that are hardly recycled. Ecopixel

has developed several materials including Trashplast, a plastic made from Belgian household trash; Low Density Polyethylene (LDPE) from industrial waste; Polyethylene of Raised Temperature Resistance (PERT), also from industrial waste; a mix of Polyethylene (PE) and Polypropylene (PP) named TAPS from household waste; and Alabaster, made from recycled PE bags that is 100% recyclable. They also offer sheets of these materials for other manufacturers and designers (Ecopixel, n.d).

Ecopixel clearly shows two circular strategies: design for multiple cycles, giving waste a new life cycle by keeping plastics that would hardly be recycled in circulation; and design for resource conservation by also stepping away from sourcing materials from finite resources like fossil fuels.

While their solutions provide a great effort to rescue materials that would otherwise end up in landfills, there does not seem to be a strategy in place for their product's end of life. Additionally, as some of the colored plastics pellets are melted and pressed against each other, it would most likely be melt completely as it would be too hard to separate, resulting in a less aesthetic color that is less likely to be used again.

Key materials employed	Sourcing	End-of-life solutions	Segment/area
LDPE, PE, and other plastics	Industrial and household waste	• Recovery of materials • Recycling/Upcycling	Material, manufacturing, homeware, furniture & consumer goods

Table 3: *Ecopixel overview of strategies*

Gerrard Street

Gerrard Street is a brand of modular headphones that compete with both low-priced and premium alternatives. While hi-end products from luxury brands are often made of higher quality and are more frequently repaired, cheaper products break easily, and it is usually cheaper to buy a full replacement.

Through research, Gerrard Street founders discovered that most headphones have similar issues or the same parts are consistently damaged. The audio jack cable being an example of these parts. Thanks to these insights, the brand adopted a modular design that allows only the damaged component to be replaced.

In addition, Gerrard Street's business model is based on offering their high-quality products through a monthly subscription as well as a one-time purchase, both options with a lifetime guarantee that includes free repairs. People that get a subscription have the flexibility to replace their headphones, switch to a different model or return the pair at any point, only paying for as long as they use them, while the purchased option offers free repairs too, only with a larger investment.

Gerrard Street is the first brand that offers headphones as a service, re-

Key materials employed	Sourcing	End-of-life solutions	Segment/area
Audio electronics, plastic	*Unknown*	• Refurbishing • Upgrading • All damaged, or obsolete parts are retrieved and re-used, re-purposed or recycled.	Manufacturing, Audio electronics

Table 4: *Gerrard Street overview of strategies*

thinking the concept of ownership, making high-quality product accessible to most budgets (Gerrard Street, 2022).

This product is a clear example of circular design strategies such as design for multiple cycles, with materials and components being reused, repaired or recycled. This is especially important as a way to reduce not only for plastic but electronic waste (or e-waste), which is one of the most toxic types of waste, but also one of the hardest and least recycled types, often dumped or sold illegally in Asian countries (Joseph, 2021). Another circular strategy seen is design for long life use of products, as the brand is focused on using high-quality technology and durable design in a standardized, modular fashion, extending the headphones lifetime in a way few electronic products can achieve. It is important to note that the two founders are graduates from Industrial Design, decided to change the industry. Gerrard Street is currently looking to expand to other products such as speakers and earbuds, a true challenge considering wireless earbuds are usually not design nor manufactured to be repaired. (The Hague University, 2021)

Patagonia worn wear

There are numerous examples of increasing efforts in the fashion industry to be more environmentally friendly and circular, this does not come as a surprise, considering a recent McKinsey research report that shows how the fashion industry "emits about the same quantity of GHGs (Green House Gasses) per year as the entire economies of France, Germany, and the United Kingdom combined" (Berg et. al., 2020). And with the increase of fast-fashion brands in the recent years, which develop new clothing models at very low prices, often reflected in lower quality product and standards, often ending up in landfills or incinerated. This issue has driven brands to look for more conscious and regenerative business models. A highly acclaimed brand known to offer high-quality, long-lasting, responsibly sourced outdoor clothing and apparel. The brand is also most notoriously known for offering repairs to their clothes. All their retail staff are trained to handle simple repairs, and any larger jobs are handled in their garment repair facilities. Moreover, they have partnered up with repair expert iFixIt to produce a collection of repair guides for customers to repair their own clothing (Fashion and the circular economy: Patagonia Repair, n.d).

Additionally, their more recent Worn Wear initiative promotes the prolonged use of their clothing, inviting consumers to return their used Patagonia clothing for credit on used or new garments. The returned items are repaired, recycled, or repurposed, then sold again in their Worn Wear website or events (Worn Wear, n.d.).

One of the main strategies displayed throughout Patagonia is design for multiple cycles, by making smalls repairs available in all of their stores, sharing guides to fix and care for their own clothes, and offering additional repair services for free (only covering shipping fees), but also by refurbishing used clothes

Key materials employed	Sourcing	End-of-life solutions	Segment/area
Hemp, polyester, and other textiles. Also employing sustainable fibers, natural rubber, organic cotton and recycled materials.	Used clothing from customers; garments produced in Responsible Factories, Farms and Mills in Asian and American countries. Recycled fabrics from waste products.	• Recycle	Manufacturing, Fashion

Table 5: *Patagonia overview of strategies*

to be sold again, allowing them to be used for many more cycles. The second strategy is design for long life use of products, which is exhibited through the manufacturing of high-quality products that are designed to last, and through investing in great customer experiences that create brand loyalty, ultimately promoting trust and attachment to their products.

Finally, a perhaps less obvious strategy they employ is design for systems change. Aside from their commitment to social responsibility throughout their supply chain, they are highly transparent on their product sourcing, which include innovative, low-impact, organic or recycled fabrics and materials.

Combined with the use and end-of-life approaches mentioned before, they are also making a statement on consumerism. Their highly popular advertising campaign usually accompanied by the headline "Don't Buy This Jacket" (Patagonia, 2021) calls people to consume less and only buy products that they truly need. The company called it hypocritical to work for environmental change while encouraging consumers to buy more, and the fact that the ad first ran during Black Friday made a bigger statement in a season where people are doing most of the holiday spending. Considering, they donate 1% of their sales to support environmental non-profits, further promoting environmental preservation and restoration, Patagonia is a clear example of a company committed to systemic change.

Kartell Bio Componibili

Kartell is a worldwide recognized Italian brand of plastic furniture, they manufacture and sell high-quality, luxury furniture and work with world-class designers. Although it is a brand recognized for using materials derived from fossil fuels, in recent years they have made ambitious efforts to shift to more environmentally friendly practices. Guided by their 2020 "Kartell Loves the Planet" manifesto, they emphasize their commitment to improve and implement more sustainable strategies, recently reflected in the use of organic or recycled resources as their raw materials (Kartell Loves the Planet, 2020).

One particular piece that came from this project is Bio Componibili, a fully sustainable version of their best-selling storage units made from bioplastic. The brand partnered up with the Italian bioplastic producer Bio-On to produce this signature product with a biopolymer derived from agricultural waste which is refined to make a high-quality product that can be injected into a mould just like a regular plastic. The material has a USDA (United States Department of Agriculture) certification and proves biodegradable in water and soil. While this is not the first attempt to make a furniture piece from a renewable material, it is the first one to be made in an industrialized way for such a high-profile brand. In this way, the bio Componibili unit clearly employs the strategy of design for circular supplies, even though this is a high-quality product, the fact that it can biodegrade back into the environment rejects the concept of waste from their product.

Nevertheless, there is little information regarding how this product is supposed to be disposed of, and while Biodegradable certification guarantees the natural biodegra-

Key materials employed	Sourcing	End-of-life solutions	Segment/area
Bioplastic	Sourced from Bio-On which produces material from agricultural waste	• All product packaging is made of recyclable and regenerable material • guaranteeing product biodegradability	Manufacturing, homeware, lighting, home and contract furniture

Table 6: *Kartell BioComponibili overview of strategies*

tion of products in a natural freshwater or soil environment, it may still require specific environmental conditions such as temperature, humidity, oxygen levels, etc. (OK biobased n.d.).

The second strategy displayed not only for this product but across Kartell's portfolio is one of design for long life use of products. This is clear as the brand consistently delivers high-quality products that are not only meant to have a lengthy life, but create an emotional bond considering these as luxury or designer pieces. Lorenza Luti, Kartell's marketing and retail director states "what we do should last for a lifetime, it's not just one use and then you throw it away" (Kartell's design-led solution to the plastic issue, 2018). By creating this emotionally engaging products, Kartell is implicitly encouraging customers to retain their products for longer.

Research Findings

The aim of this exploration was to analyze existing products and brands employing approaches to circular design. By selecting case studies in a mass production environment allowed to compare different sectors and find patters on what the most common strategies are being used. Some of the highlights from this study include the following observations:

Benefits to companies:

- Brands that are open about employing circular or sustainable practices could improve public perception and acceptance.
- Circular design can help companies improve efficiency and reduce costs by closing resource loops and investing less in extraction of virgin materials.
- Standardization could be an effective strategy for manufacturing companies, reducing redundancy of tools and fittings.
- Companies can evolve from manufacturing-only to service providers, so that they can offer, maintenance, replacement, or collection services, which could indirectly improve customer perception and loyalty, while making their supply chain more efficient.

Benefits to consumers:

- Subscription services where the ownership of the product remains with the company are a great tool for making high quality products accessible to lower income markets, although the costs can build up over time.
- A higher quality product, technology, or service can provide a better value for customers, although eco-benefits are not recommended to be the main selling point (Moser, 2015).

Key Considerations

- Transparency is important in terms of material sourcing to correctly assess a products' environmental impact to avoid a subjective evaluation or "green washing", a business practice of making false or unsubstantiated sustainability claims (Reuters, 2021)
- Companies should educate consumers on how to properly dispose of their products and materials.
- Creating highly desirable products will encourage consumers to take care of them and make them last longer. As luxury items are more valuable, they are more likely to be repaired or sent for maintenance by the user. By contrast, cheaper products are rarely worth the cost of repair.
- Although recycling plastics is a common and easy way to reduce waste and emissions in the industry, its impact rating is so low that it should be among

the last options (Crunden, 2022).

- Recycling and collection facilities vary from location and government, so it is important for consumers to be aware of local regulations and companies to be mindful of where their products are being used and disposed of.
- Companies should have a clear EOL strategy to ensure that products are designed and manufactured to be repaired or reused.

Barriers

- Most bioplastics and biodegradable or compostable materials require specific environmental conditions to degrade, such as industrial facilities, which are not accessible to most people.
- It is harder for electronics to embrace a circular approach, as their components are hard to retrieve or recycle. Which is why there is so much e-waste.
- Despite people's enthusia for recycling, municipal programs vary widely, and people may throw items into bins without verifying that they can be recycled.
- Systems change is the hardest strategy but by visualizing their organization and market as part of a system, like Patagonia, companies can get a better picture of intervention points and make fundamental change that integrates all parts of the organization into working for a common goal.

> **"The resources we need are no longer in the ground, but in landfill"**
>
> **- Treggiden, 2021**

A recurrent pattern observed from this study was that most strategies revolve around closing material and resource loops. Author Katie Treggiden appropriately says in a design magazine article: "The resources we need are no longer in the ground, but in landfill" (Treggiden, 2021). As she explains how many of the current environmental challenges could be addressed by eliminating waste, she highlights that for new products, this should start at the design stages. This will be an important consideration throughout this research.

Current Practice

Expert Interviews

Following a literature review and an analysis of the design and manufacturing stages of products, primary research in the shape of interviews provided further understanding on current practice and approaches to sustainability from various fields. Through a series of interviews with experts in domains related to design and manufacturing, the objective was to gather insights on the current challenges to sustainable design within the product development process.

In order to get a wider range of perspectives, four different categories of interviewees were cosidered: Academic, Design, Production and Recovery.

Participants

The criteria for selecting each participant included at least a 3-year experience in a role as defined by each category:

- **Academic.** Faculty position (professor, instructor, Associate professor, or similar) in a design program with an interest in environmental sustainability. Or, a researcher in the topic of environmental sustainability in relation to design, manufacturing, material design or similar.
- **Design.** Industrial Design, Architecture, Automotive-, Environmental-, Packaging Design or similar, with fundamental knowledge of product manufacturing processes.
- **Production.** Engineering, Industrial Design, CAD Technician, or similar, with a focus on product manufacturing.
- **Recovery.** Solid Waste Management, roles related to material or resource recovery, environmental advisory, or policy, or similar.

The semi-structured interviews asked several questions regarding their professional experience and knowledge regarding the design, development, or waste management of physical products, reflecting on practices, or lack-thereof, that support environmental sustainability. By interviewing people from different categories, the development of the final toolkit would be informed not only by theory from literature, but real voices in the subject, acknowledging their opinions on what are key areas to focus on.

While the original target was to interview at least two participants from each category, the final input included 5 people from the Design category, 3 from Recovery, 2 Academic and only 1 from Production (manufacturing), resulting in a total of 11 participants. Nonetheless, the gathered information provided enough insight for the project, however it is acknowledged that any future iterations could benefit from a wider pool.

Table 7: *Sample questions from expert interviews*

Category	Question
Design	• What are the material selection criteria for particular products? • If any, which environmental considerations do you have regarding the product's life cycle in your process? • What are the main barriers to implementing more sustainable design and manufacturing processes for consumer products?
Production	• What could designers do to make your job easier or more efficient? • What manufacturing processes are done in your place of work and what are the wastes generated from these (that you are aware of)? • How do you envision the dynamic of work between designers and Manufacturers in the future in respect to sustainability?
Academic	• Where do you think industry and policy efforts should be focused on in terms of sustainability? • How do you think we can avoid green washing (when businesses use marketing practices to give a false impression of a product or company being environmentally friendly)? • How do you think foresight or critical thinking about the future can better support designers to address these and other challenges?
Recovery	• What do you think is the most common misconception about recycling or solid waste management? • What is your opinion on the use of biodegradable or compostable materials? • What could designers and manufacturers do to make the disposal or recovery of materials more efficient?
All	[After describing the circular design strategies from the Circular Design Framework] • What potential barriers to implementing any of these concepts do you think would be faced?

Some of the more general questions talked about their job functions, workflow and their vision of the design and manufacturing of products in the future, and depending on each category, there were specific questions to their sector, discussing their perceived influence in the product development process, barriers to implement sustainable practices or their point of view around the role and involvement of different stakeholders in strategic decisions.

The last few questions were the same for each category, asking whether they considered a Circular Economy to be achievable with current technology and knowledge, what they considered would need to change to fully embrace this model, and potential barriers to implement circular strategies for product design. Sample questions are listed in the table below.

Analysis

After finalizing the series of interviews, an Affinity Mapping activity was conducted to analyze the responses from participants. As a first step, the answers and additional comments from the interview were transcribed onto sticky notes, excluding answers that were irrelevant or provided no value to the goal of this research.

The next step aimed to identify common patterns, grouping the stickies into 14 main categories and giving the groups a title that encompassed a general theme, such as Ethics, Consumer Behavior and Barriers. Following this, a further exploration was done within each category, using additional keywords to expand on the specific ideas or topics that were being addressed (E.g. Greenwashing, Producer Responsibility, and Misleading Information were topics identified within the Ethics category).

Finally, a counting was done to assess how many times a specific topic was mentioned. This allowed to rate which topics were brought up the most, selecting the top 20 categories as high interest topics for intervention.

Using an adaptation of the Intervention Wheel from the Systemic Design Toolkit (Van Ael et al., n.d), the category statements were phrased into action sentences or "interventions" and organized in their appropriate level of impact. The wheel is based on the paper Leverage Points: Places to Intervene in a System (Meadows, 1999), and it allows to identify what interventions could provide a more effective and meaningful change.

The 12 levels or points of intervention are organised in increasing order of effectiveness as shown on Appendix A. The lowest level, "Constants, parameters and numbers", covers decisions about limits that should be reviewed or changed, while the highest and most effective intervention points to "Paradigm Shifts", refers to transcending paradigms and changing world views, hence, the hardest to achieve.

Findings

After analizing the interview responses through the methods discussed above, a resulting list of 20 interventions provides potential actions to consider to integrate sustainability into the system around product manufacturing and consumption, touching on subjects ranging from policy change to re-evaluation of product ownership. The following list presents the 12 points of intervention, arranged from higher to lower impact with their corresponding intervention. Further activities are provided based on the interview insights and responses as opportunities for action.

1. Paradigm shifts

- **Considering all waste as a resource.**
  Potential ways to achieve this could include to engage with local markets and industry to create a feedstock network that streamlines industry waste to supply other companies; taking materials from landfills; prioritize waste recovery efforts withing the product development process; follow a Cradle to Cradle strategy; preventing GHG emissions or implement capturing technology that can potentially be transformed into other products.

2. Alter mindsets

- **Shift paradigms around ownership and consumerism**
  Avoiding fast fashion and trends; challenging the consumerist mindset to favor sufficiency; focus more on quality over quantity or price for products; shift away from a throwaway economy and rethinking ownership to embrace leasing models; or analyze if products address human needs and provide true benefits to society before production.

3. Change goals

- **Change from profit-driven business models that emphasize financial benefit**

above environmental and social responsibility
Integrate Sustainable Development Goals to organizational goals; change from a low investment-high return focus in favor of producing high-quality products; rationalize low margins in favor of conservation; reduce demand-promoting or incentivizing marketing techniques; accept that sustainable efforts will slow down profit.

- **Design for Responsibility**
Leverage designer's skills and knowledge to make best material and design decisions to favor sustainability; create intuitive or persuasive designs to encourage proper use & disposal; foster a product lifecycle and disposal-informed design process, advocate for ethical design, manufacturing and marketing practices; reject programmed obsolescence; support designer's authority to make material or process decisions or recommendations.

4. Self-organization

- **Use a learning, iterative design process**
Improve or develop an adaptive, design-driven process informed by research and with input from other areas; analyze product & customer journeys and iterate based on findings; leverage and support designers' multiple skills & knowledge on different subjects; integrate a systems thinking approach to understand the product's lifecycle touchpoints and implications to the environment; revise and adjust process in a project-based approach vs. a one-fits-all model.

- **Implement more comprehensible effort opportunities for consumers**
Make it easy for consumers to contribute based on their realistic capacity, knowledge and impact; reduce responsibility & unreasonable expectations for consumers in terms of sustainability; educate about environmental impact and inform consumers about their product's lifecycle and EOL (proper use, disposal, etc); simplify process for consumer disposal or reuse of products.

5. Rules and regulation

- **Use Foresight to plan for uncertainty and adapt through different scenarios**
Step away from a homogenized vision to acknowledge that an 'ideal future' will be different everywhere; line up technology & innovation to set realistic expectations; use a convergent thinking to visualize possible developments, impacts, and futures; consider benefits for future generations; look for trends and signals of change to ensure strategy and product resiliance; assess current and future impact and react promptly; recognize status quo and potential changes to favor positive futures.

- **Implement Policy & Regulation to enforce sustainable practices**
Institte third-party environmental regulatory bodies to avoid insincere self-regulation from companies; legally impose metrics and standardization to manage impact; impose harsh fines & taxes to ensure producer responsibility and compliance; mandatory environmental impact & health implications assessment; streamline policy implementation to improve and regulate faster.

6. Information flows

- **Expand consumer knowledge and education**
Empower consumers to advocate for better, healthier products and make it easy to make right purchase and EOL decision; increase awareness on the hierarchy of efforts and impact from an individual to collective and organizational level; avoid Wishcycling and educate to recognize and reject Green-

washing; increase climate & CE awareness; challenge & advocate for better, more sustainable products and industry practices.

- **Increase transparency of supply chains**
  Enforce ethics compliance to improve trust in companies' labourpractices; increase disclosure and transparency of products' and materials' extractions, properties and sourcing; integrate methods to track products and materials throughout supply chains.

- **Improve & facilitate industry knowledge**
  Integrate decision-making frameworks to promote informed decisions and use of the right tool or process for the right problem; reduce Greenwashing & avoid producers shifting the blame to consumers or external entities; understand and inform the whole supply chain's inputs, outputs and impact within the design & development areas; increase awareness on the organization's overall environmental impact and potential EOL strategies internally and externally; adopt or promote process-and material-informed design practices that favor sustainability.

7. Reinforcing feedback loops

- **Provide incentives for producers**
  Make environmental certifications more accessible; support SMBs & green companies, providing economic support, benefits or tax breaks; replace fuel-based materials with lower-cost sustainable material alternatives; support transition to and lower costs of sustainable energy or materials; improve energy and process efficiency to reduce costs; reward, promote or give positive publicity to green or transitioning companies to improve their reputation.

8. Balance feedback loops

- **Provide disincentives for producers**
  Make producers justify & compensate for damaging or unsustainable practices; increase the cost of non-renewable energy and materials, penalize Greenwashing; implement barriers for companies to externalize their impact; integrate accountability measures and liability for producers to improve their practices; impose government-required supply chain assessment & strict auditing.

9. Delays

- **Design for a long life use of products**
  Support strategic design engineering to guarantee product longevity; strive for heirloom quality through high quality parts and materials; promote product attachment that incentivises care and repair instead of disposal, design emotionally engaging product experiences to promote emotional durability.

10. Physical and digital structures

- **Integrate EOL Solutions for materials & products in design and manufacturing process**
  Provide and guarantee proper disposal conditions of products; reuse parts and recycle materials whenever possible; offer product maintenance, replacement or take back programs; redesign production systems to streamline or implement material and waste recovery streams; consider inputs and outputs throughout material and product lifecycle reducing scrap and waste; design products that are easy to disassemble, repair or refurbish; integrate modularity or other design strategies to simplify repair or disposal, avoiding landfills.

- **Use & improve sustainable materials**
  Use regenerative or recycled materials; avoid petro-

leum-based materials and prioritize bio-based alternatives; understand and follow proper bio-material handling, processing & disposal; avoid fused materials to ensure a fully circular loop; consider implications of using sustainable materials; lower quality standards for alternative materials to reduce rejects; support and justify use of sustainable materials to improve future performance.

11. *Buffering capacity*

- **Integrate strategies to compensate for brief constraints (trade-offs)**
  Implement trade- off solutions to adapt to technology gaps; identify boundaries on early stages to ensure efficiency & feasibility of products; procure flexible brief constraints (e.g. budget restrictions); increase stakeholders awareness around capacity & complexity to manage expectations; analyze potential material and manufacturing processes alternatives against product requirements and environmental impacts; document material and process trade-offs.

- **Create an internal material reference platform**
  Ensure design and manufacturing departments understand material properties and capabilities; document material research for future reference; create a library or database for sustainable materials or products; provide and document material substitutes or alternatives; create a physical or digital showroom; simplify material environmental impact assessment.

- **Increase and promote alternative sourcing opportunities**
  Expand material research and sourcing efforts; increase availability of material stock and samples; develop or improve sampling solution systems; promote and support local sourcing over international options; consider alternative streams for feedstock (E.g. landfill or industry waste); demand reasonable and accessible terms & prices from suppliers; advocate for sustainable technology, materials and product supplies.

12. *Constants, parameters and numbers*

- **Increase budget for sustainable efforts and solutions**
  Lower company margins to balance higher sustainable material costs; increase product and material innovation investment budget; promote and support alternative materials; make a case for implementing sustainable strategies throughout the product design and development process.

Circular Frameworks

Following this process, the next step was to analyze and evaluate some of the existing frameworks and tools for sustainable product design, finding common patterns, approaches and values. The goal was to determine the best practices in existing frameworks and tools to provide a guideline for the creation of a simplified toolkit. Among the analyzed literature around the topic of sustainable design and product development, there are tables comparing several of these frameworks on different criteria, but with their own perspective and specific objectives. These existing tables provided a basis on what the focus of some tools were, although for of the scope of this project those that focused on business model creation were filtered out.

Considerations

Building from previous literature, such as those presented by Van den Berg and Bakker (2015), Moreno et al. (2016), and van Sijn and Gruis (2020), a simplified table was created, with a final selection comprised of non-proprietary frameworks that focused on physical product outputs, excluding those that targeted services or business models as these were out of scope.

Additionally, to get a fair comparison, the final list was reduced to 10 frameworks, but with highly contrasting styles and approaches. It is also important to note that some interventions, such as those surrounding policy, which require a longer time and larger involvement throughout different sectors and organizational levels, were considered out of scope and intentionally left out for the purposes of this analysis and toolkit. It is acknowledged, however, their importance in making meaningful change in a larger scale.

Criteria for Evaluation

In order to analyze the frameworks without overlapping previous assessments, some reviewed criteria was the tool format, value, covered strategies and limitations. Additional criteria derived from the interview insights from aspects deemed important by the participants. For this, the interventions generated in the previous section that potentially had the most impact were prioritized, adding only a few that, although they would provide less impact, were frequently mentioned in the interviews and could be easier to integrate into a design process.

Next, the interventions that could be grouped into more general but similar efforts were combined and later reframed as simplified objectives to use as evaluating criteria, discarding those that overlapped with circular design strategies, since these were already considered in the table. The additional criteria would determine whether the frameworks marginally address these topics.

One of the generated criteria was assessed the adaptability of the frameworks to an existing product design process, a key goal for this research project. Furthermore, the review of existing tables revealed that most frameworks around sustainable design and circularity are done with an academic point of view, undervaluing the effective application of these in a real work environment aside from testing in a workshop-like environment.

To assess if these framework could be integrated into an organization's process, a series of questions that were believed to determine the ease of adoption of these tools were crafted from interviews and research insights. The questions included: ***is the flow of the framework similar to an average design process?, would it require organizations to significantly change their process?, is it flexible or can it be customized?, does it require previous training or instructions?, can it be applied to other sectors or companies?, does it need to be followed in full or can some pieces be used as applicable?***.

Findings

A summary of observations worth highlighting from this analysis as well as previous comparison tables from literature are listed below and will be considered for the creation of the toolkit in the next stage.

- The frameworks that met most of the criteria provided case studies, which allow for a better understanding of the strategies in practice.
- Several tools provide cards with brief descriptions of circularity strategies, these point to a practical example to showcase circularity terminology and principles without requiring extensive reading or explanation.
- Some frameworks have many steps, which can be tedious or complicated to implement, increasing rejection of their adoption.
- Frameworks such as LCA and C2C, although they guarantee a detailed evaluation throughout

the organization and its supply chain, can take months and be quite expensive.

- Few frameworks seem to address an analysis of future implications beyond End-of-Life strategies and could benefit from foresight or trend research that may affect the behavior and impact of products.
- Some tools that use modules or sections tend to repeat information between them, which is redundant.
- Most of the tools require to be completed sequentially, which may not be efficient in a time-constrained process, therefore those that do not have codependency seem favorable as a "mix and match" style to use as appropriate.
- The table can be further improved to provide guidance on frameworks that designers and organizations can look into for specific objectives.

Ideation

Throughout this research, many opportunities to enhance the design process were discovered, and following the analysis of insights from primary and secondary research, various recurrent considerations revealed different pathways that designers and organizations could use to improve their product development process. While some were considered to evaluate existing frameworks shown in the previous section, the list below summarizes the key criteria that helped to develop an actionable toolkit.

Criteria for success

- Toolkit adaptability to support an existing design process
- Provide a combination of actionable items and guiding questions and instructions
- The tools should not be sector, product or company-specific
- Modularize the tools so they can be used independently
- Include a foresight element or promote future-thinking
- Provide a decision-making tool to select the best solutions
- Present strategies as relevant and include examples
- Provide strategies to analyze or overcome tradeoffs
- Mindful of project constraints
- Guide the understanding of different levels of interventions
- Format and style that is easy to follow, such as card decks
- Does not add an unreasonable amount of work to the process

Prototyping

Building from the series of frameworks analyzed that contained criteria considered valuable for the creation of this toolkit, the following conceptual set of tools was developed that can help translate theory into practice without requiring extensive training or education on the circular economy.

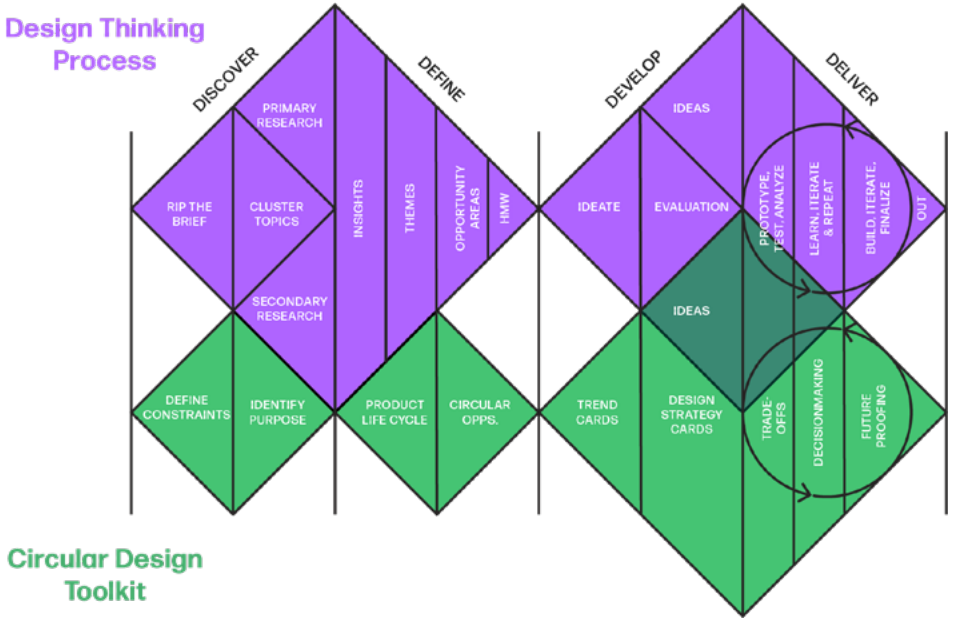


Figure 10: *Design Thinking and toolkit integration*

The Circular Design Toolkit

The toolkit created for this project was designed to match most design processes, although a Double Diamond Design Thinking (Ball, 2019) process structure is used as an example reference. Similarly to this methodology, the toolkit adjusts to four stages Discover, Define, Develop and Deliver, presenting a set of tools for each one.

The tools are independent and can be used continuously, separately or individually to assist a design process depending on the available time and flexibility of the project.

In the following pages, a short description of each tool with a set of instructions as they will be displayed in the final toolkit is presented along with a small graphic example.

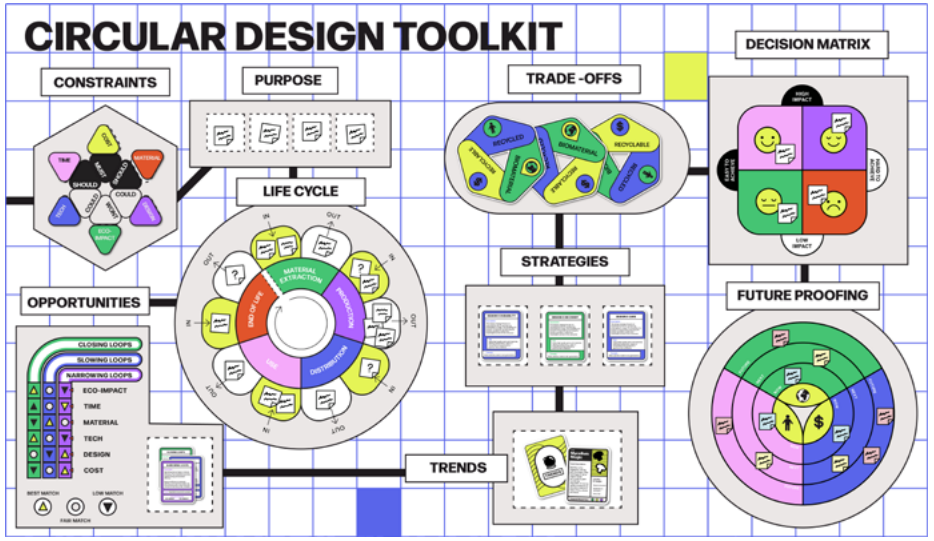


Figure 11: *Circular Design Toolkit overview simulation*

Research stage

Constraints

Recognizing constraints allows to define realistic project boudaries. These are obstacles, barriers and conditions that can affect the design and development of the product. Some of these constraints can be flexible, although there are generally fixed barriers that define important aspects that the designer must be aware of. Based on the MoSCoW method (Clegg & Barker, 1994), the simplified arrangement in this tool recognizes each constraint's level of priority and flexibility for a more efficient process.

Figure 12: *Example constraints placed according to priorities*

How to use

1. Identify your project constraints. These can be internal (provided by management or a design brief) or external (fixed, invariable restrictions such as budget or technology).
2. Read the descriptions below each constraint category and analyze how detailed your constraints are.
3. Identify your constraints priorities in the Must, Should and Could sections.
4. The Eco-impact is predefined as a fixed constraint and cannot be changed.

Time	Cost	Materials
Research time • Product design time • Manufacturing time • Lead time • Other	• Material costs • Cost of manufacturing processes • Net cost • Product price point • Margins	• Type • Resources consumed • Supplier options • Sampling availability
Design • Shape • Form • Size • Color • Finish	**Technological Capabilities** • Manufacturing processes • Experience / knowhow • Knowledge • Skills	**Environmental impact** • Emissions • Waste / rejects • Finite materials • Outsourcing • Pollution

Table 8: *Examples of constraints*

Purpose

As a simple step to follow the specific setting of this project, it is important to analyze the implications that the product will have during and after the use, as well as to explore the real conditions to which it will be exposed to. Defining the real purpose and the reason for which the user will purchase this product will provide the designer with a valuable insight to create an informed and meaningful product.

How to use

1. With the help of the cards, follow the prompt questions to identify and discuss the purpose of your project.

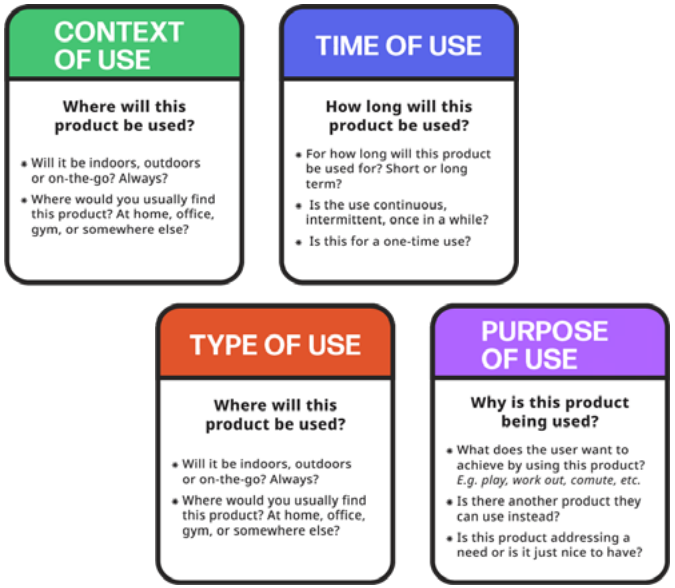


Figure 13: *Purpose Cards*

Product Life Cycle

In this step, the goal is to identify the inputs and outputs of a similar product throughout its life cycle. This may be considered as a draft, since the actual design concept is just starting to take shape. By mapping out the materials and resources needed as well as the intended and unintended outcomes of the production process, you can identify the most critical stages in terms of environmental impact as well as any uncertainties in the supply chain.

How to use

1. Start by thinking of products that are addressing your design challenge and try to answer what are their most **basic inputs**? *Think of the inputs as any raw material, energy and resources necessary to create this product. The final output will be the final product. For now.*
2. Think about the necessary processes and activities that could be necessary to create this product. What challenges can you identify?
3. Move on to each stage and explore the prompt questions to fully map out the **product life cycle**:

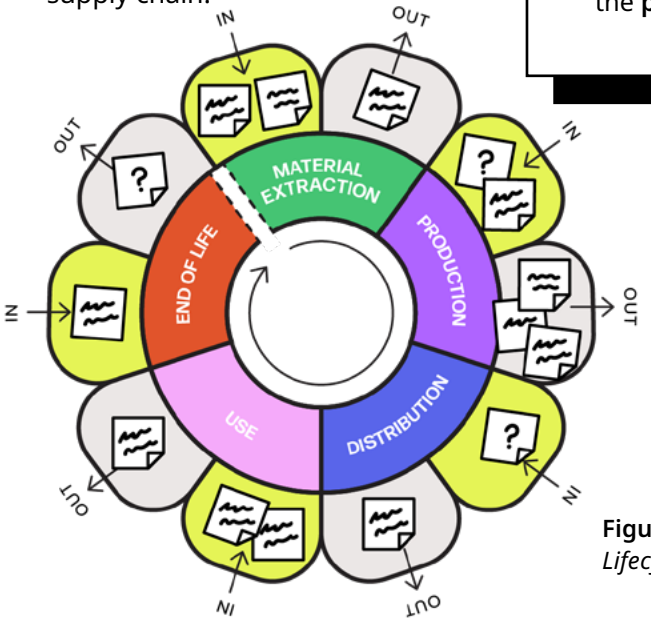


Figure 14: *Visualization of Product Lifecycle wheel with stickies*

Table 9: *Questions according to each product life cycle stage*

Product Life Cycle Stages	
Material	• What materials are commonly used for these products? • What materials does your organization have access to? • Where are they extracted from? • How else can this feedtock be obtained? • Is more than one material required?
Production	• How many parts or elements make up the product? • What transformation processes are required to achieve this final product? • Does it need assembly? Where and how is it assembled? • Can all processes be carried out in a single facility? • Does it have any coatings, finishes, dyes or additives?
Distribution	• Where will the product be manufactured? And where will it be sold? How will it be shipped? • Is it made-to-order, or would it require a large stock? • Are there any steps in the distribution that can be skipped? • What are the obvious environmental impacts of this stage? • How and where does the consumer purchase the product?
Use	• How long is the product meant to last? • Can the product still function if it's damaged? • Can anyone provide maintenance or does it have to be done by the company/a professional? Can it be upgraded? • Can the product be used by several people? • Is it obvious how to correctly use the product? • Could this product be a gift?
End of Life	• What can make a user keep the product for longer? • Can this product be passed on between generations? • Can any part be recycled or repurposed? • What happens if the product breaks or it's no longer useable? • Where would it go? • Can the product be upcycled or refurbished?

Circular Opportunities

Depending on your project constraints, there will be an assessment of the degree of alignment with specific circular opportunities with the help of a table of prioritization. The table indicates which are the recommended approaches to circularity depending on each constraints leverage opportunities. Although there are other frameworks to prioritize and evaluate in a more quantitative fashion, because this is part of a creative process, it was important to provide a tool that can align with most design teams' time, knowledge, skills and comfort level.

How to use

1. Look back at your fixed and top priority constraints and identify the recommended circular approaches in the guide illustration.
2. Select those with the highest alignment with your constraints and at least one with a medium alignment.
3. Read through the circular opportunities cards to help you think how can you implement them.
4. Go back to your product's life cycle draft and start exploring how each strategy could be implemented through every stage.
5. Finally, compare each strategy against the purpose of the product and functional needs identified at the Define stage.

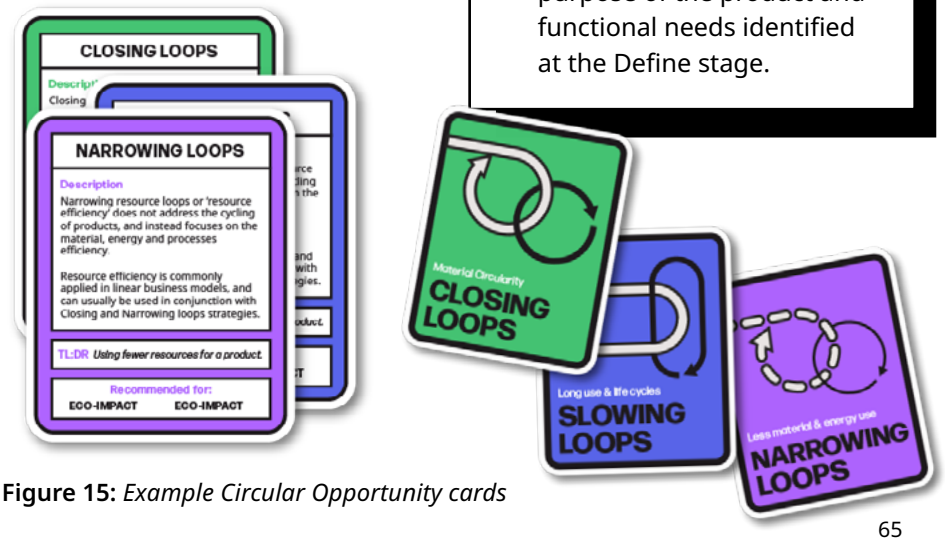


Figure 15: *Example Circular Opportunity cards*

Trend Cards

The purpose of this deck is to explore emerging and growing trends to analyze potential implications for the future of your consumer, market, or product. As you start your ideation process make sure to include these trends as you gather inspiration sources. Look for trends that align most with your organization and product purpose and think how you can incorporate them into your work.

Figure 16: *Trends SWOT question cards*

How to use

1. Grab a medium and a low priority constraint along with your fixed and high ones.
2. Browse through the trend deck and locate the color that matches your constraints. Each trend card is color coded, showing potential areas of opportunity it could impact.
3. Read the trend descriptions and use them as inspiration.
4. You can use the question cards to guide your process and explore additional implications.

Figure 17: *Example of Trend cards*

Design Strategy Cards

These cards explore circular design strategies based on the circular opportunities identified in the Define stage. Although all strategies may be evaluated, the dynamics of this section allow you to focus on those that are most aligned with the circular opportunities and your design boundaries. Each design strategy presents a brief description as well as an example of its application in real products.

How to use

1. After identifying the circular opportunities that best match your constraints, look for the design strategies deck.
2. Browse through the cards that match your results to analyze how these can be applied to your design.
3. If possible, consider exploring lower-level approaches to enhance your ideation process.
4. Select 2-3 strategies and explore how the product could successfully apply this methods.

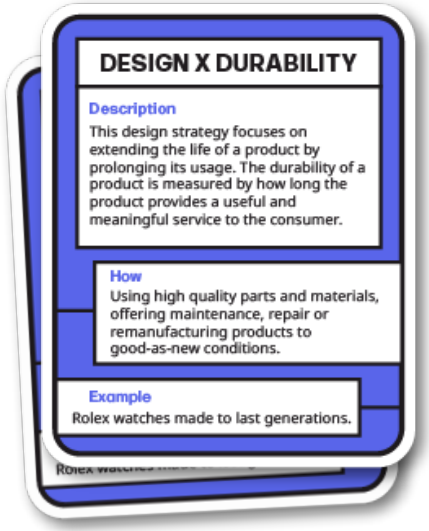


Figure 18: *Example of Circular Design Strategy card*

Trade-off Trios

After the ideation stage, it is common to have multiple promising ideas, so organizations or departments may have certain evaluation criteria based on their interests, profits, and market conditions. After the ideation stage, it is common to have multiple promising ideas, and organizations may already have specific evaluation criteria based on their interests, profits, or market conditions. This tool helps to practically analyze different trade offs with a Triple Bottom Line approach, that is, People, Planet and Purpose, understanding the potential implications or trade-offs of various sustainability strategies.

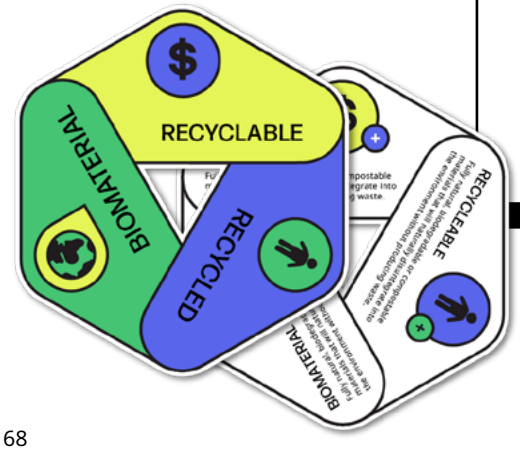


Figure 19: *Example Trade-off cards*

How to use

Ask yourself and your team:

1. What CD Strategies should we prioritize? If we cannot build this yet, what would be the second-best solution? Are there any features that we might have to compromise? Which seems like the most balanced solution?
2. Look back at your constraints and analyze. Are there any of the fixed constraints that may be negotiable? What would be acceptable ranges for which we can be flexible? Can you leverage any of your constraint opportunities to compensate for non-negotiable conditions?
3. Select at least three potential strategies and continue with your design process exploration before moving on to the Decision Matrix.

Decision Matrix

After exploring potential CD strategies and opportunities, this tool can help you decide which solutions are most viable for the business, beneficial to the planet or the user. The matrix has a feasibility and impact axis to easily identify the best concepts to move forward. For this type of assessment tools, it is recommended to include other departments such as marketing, to get a larger and more objective evaluation.

How to use →

1. Write down on stickies the title of your design concepts on this graph to help prioritise which ones to pursue. Try to stay in the top quadrants.
2. Measure the **feasibility*** of your product. Assess the degree to which a concept is possible with your current resources, time and budget.

   Within this axis, find the appropriate level for each concept by answering the questions provided.
3. Measure the **impact** of your product. Assess the degree to which a design concept provides value to consumers and meets their expectations while being environmentally responsible. Within the impact axis, find the appropriate level for each concept by answering the questions provided.

* *You may want to provide your own definition of what feasibility may look like for your organization.*

Feasibility questions

- Does it require adjusting our process, technology, or budget?
- If so, will this provide a new opportunity to learn or explore new markets?
- Does the potential opportunity justify the disruption?
- Is it possible to attain the capabilities or technology alone or through potential partnerships?
- Is it realistic within our current strategy?

Impact questions

- Is this product addressing a real human need?
- How will this product change the user's life? What will happen to the product after its useable life?
- Are the materials easy to recycle or can you introduce a recovery program?
- Does the concept meet more than one circularity principles?
- Are there any unintended outputs such as waste or emissions? Can they be reduced?

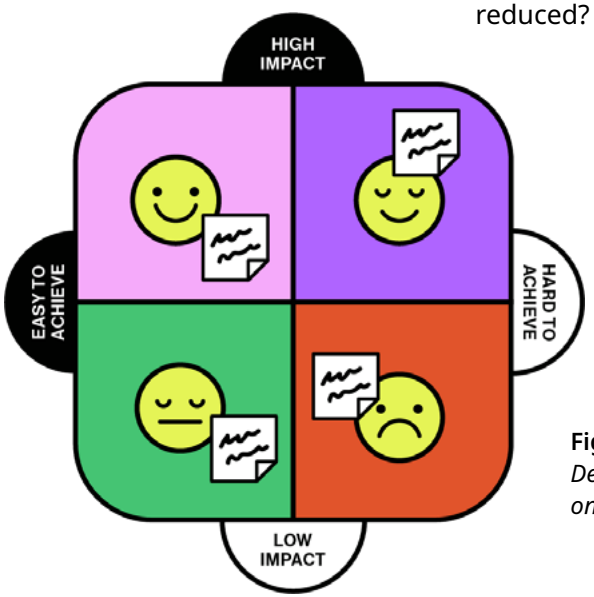


Figure 20: *Visualization of Decision Matrix with stickies on each quadrant*

Future Proofing

This tool is the final piece to assess the potential of these concepts in the near future and beyond. Although this part may be omitted, it is a valuable step in determining if the end product(s) of the design process will stand the test of time and any potential for improvement. The **pie radar chart** allows to explore opportunities that may be presented by adjusting or removing product constraints, or by imagining future possibilities.

How to use

1. Use three different color stickies for each level. Keep the same colors on all three sections (People, Planet, Profit). Follow the questions for each level from the table below, write down your insights and place them in the appropriate section.
2. Discuss what your product is vs. what it could be and discuss with your team how you can plan and design for the future.

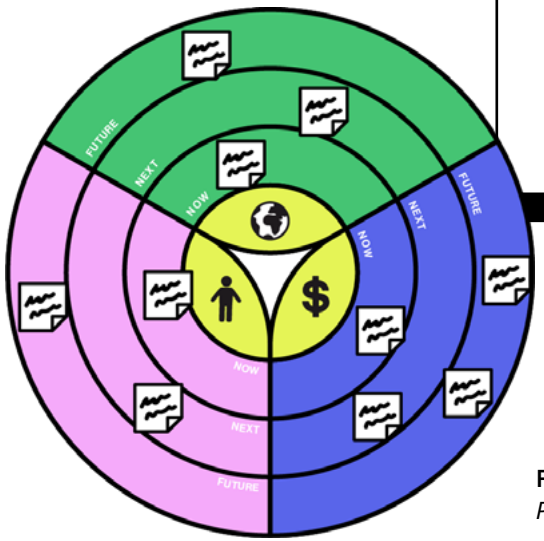


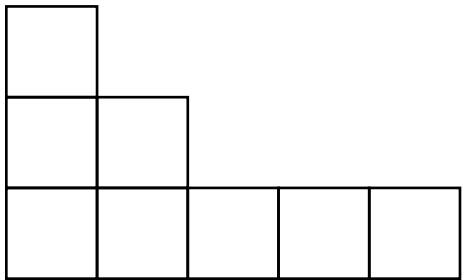
Figure 21: *Visualization of Future Proofing radar map with stickies*

Table 10: *Guiding questions to evaluate future implications according to each target (People, Planet or Profit)*

People	
NOW	• What are the benefits and f|eatures perceived by the user and society? • Will these change within the first 6 months? • How are the product interactions?
NEXT	• How will the user take care of the product during the first year? • What will happen if the product breaks? How will this impact the user? • What additional features could you provide without creating a new product?
FUTURE	• How would an upgrade for this product work? • If your initial constraints were more flexible, what are some characteristics that you could improve? • If the trends you observed before continued to grow, how could your product be affected?

Planet	
NOW	• What are the environmental impacts of manufacturing this product? • Are there any interventions currently addressing similar issues? • Are you extracting any finite resources for the creation of this product?
NEXT	• Where are the most negative impacts in product's life cycle? How could you eliminate them? • How could you integrate emotional durability with the user to promote product reuse, maintenance and repair? • How will they dispose of it when it's reached its usable life?
FUTURE	• Will the integrity of the materials stay the same for the first 3-5 years • How could you avoid any materials to end up in landfills? • If the climate crisis continued to grow, how will this affect your product?

People	
NOW	• Is the product being produced and assembled locally? • Where are your highest costs for this product? • How will the market receive your product? Is there an additional cost for related services?
NEXT	• Can you develop or launch a new product upgrade or service? • How can you reduce costs for producing this product? • How can you gain a new customer base for this product?
FUTURE	• If you could eliminate your initial constraints, what would you improve for your product? • How will you grow your business in the next 5 years? • What would need to change to make your product 100% local?



Recommendations

While this toolkit aims to provide a practical guide for designers to implement sustainability principles, it is important to acknowledge the limitations given the scope for this research, for which some recommendations are provided.

1. ***Keep learning and do your research.***

Although it is intended that this framework facilitate the integration of Circular Design in a more efficient way and that it adapts to most design processes, research on this topic continues to grow, so it is recommended to further one's research with reliable, unbiassed and updated sources.

The book Cradle to Cradle (2002), in addition to being the driving force behind this project, is a good introduction to the concepts and principles of circularity. Despite having been published over 20 years ago, it has served as a basis for the field of product development, evolving into a globally recognized certification that is still valid. Similarly, the Ellen MacArthur Foundation has worked with organizations, policymakers and academia promoting the transition to a circular economy. Their website The Circular Design Guide (2018) contains a series of resources, case studies and methods to help understand and create circular innovations, regardless of the reader's background.

2. ***Responsibility as a Design process.***

It is a difficult task in organizations where the organizational structure is siloed, but it is the responsibility of the designer to use their knowledge, skills, and influence so as not to perpetuate a 'throwaway' consumerist system that ignores the environmental crisis and the role of the designer in the creation of these products.

Although this represents a dichotomy for the job, the planet has an excess of material objects that do not respond to a need. The value that each new product concept brings must be analyzed, not only for the organization, but also for society. In addition, it is important to investigate and understand the environmental implications of the mass production of these items, designing responsibly and mindfully.

3. ***Mix-and-Match.***

There is a wide selection of tools, guides, resources, and frameworks at the intersection of design, innovation, and sustainability. The application, context, and focus of each one may vary, so there is no one-size-fits-all. Although this project presents an approach to integrate some strategies in a typical industrial design process, it is important to consider what the objectives of each project or stage are before selecting a framework.

This toolkit was created in a modular fashion, so that each section can be used independently within the respective design phase as deemed appropriate. However, there are other frameworks that provide different values and more in detail on issues of manufacturing, material chemistry and emotional durability strategies, so it is encouraged that designers look for the tools that are most compatible for their design process and works for the advantage of the project.

Conclusion

While the challenging environmental crisis and the significant involvement of the manufacturing industry is common knowledge, organizations continue to socialize the problem by promoting recycling and concepts such as “carbon footprint”, shifting the blame and guilting people about their ecological footprint (Kaufman, 2021). Companies often approach environmental activities as a publicity campaign rather than holding themselves accountable and taking concrete actions to reduce and offset their impact.

Capitalist consumerism has become a wicked problem, and as such it is almost impossible to solve, as there is no single solution due to the complexity of its ramifications. The accumulation of consumer products in landfills being one of these. Although it is acknowledged that there is a great interest to solve this pervasive problem from institutions, governments, and society, it is important to recognize the role of industry as a not-so-invisible machine, mass producing with minimal restrictions and liability. Consequently, models such as the Circular Economy have gained notoriety as a way to slow down and, in theory, eliminate the concept of waste in the consumer economy.

It is from this concept where the motivation for this research is born, driving the concern to address the insufficient sustainability practices in the creation of products. As these objects have passed through the hands and minds of designers, it is impossible to ignore the unexploited potential of their role in this matter. Thus, this project aimed to answer the question “How might we encourage designers to embrace circular design practices?”. Through a combination of different research methods, not only an extensive collection of research and frameworks on the topics of circular economy, sustainability and product design were analyzed, but also expert opinions were considered to understand what strategies are being used in the industry and academy currently, as well as its limitations and areas of opportunity. In response, a toolkit was developed as a way to provide designers with the tools to adopt a circular design practice.

Findings

One of the insights discovered through this research that is important to highlight, is the consensus that product designers have a broad skillset and knowledge base in matters of materials, manufacturing processes, ergonomics and creativity, driven by a will to provide valuable solutions and minimize their knowledge gaps. Recalling a secondary question of this research “How might we give designers the autonomy to make decisions regarding product design to favor or achieve a circular economy?”, this toolkit aims to recognize and exploit the opportunity of design roles, offering tools that allow them to explore alternatives and analyze the implications of each design, making informed decisions for the benefit of the environment as well as the company.

Another important discovery was the fundamental role that brief, operational and organizational constraints play to determine the potential sustainability strategies that can be implemented on each project. Relating also to the third question of this research, “How might we make environmental sustainability more intuitive to supporting stakeholders in the development process?”, a brief module was included in the toolkit that allows to evaluate different trade-offs based on project constraints to streamline the process and interactions between departments, allowing to implement strategies cognizant of internal and external conditions.

, the insinuation that adopting a circular economy and responsible consumption requiring a large-scale

effort was highlighted, implying not only firm interventions by government agencies, but also a paradigm shift for society and the economy, getting rid of a culture of waste and monitoring the participation and involvement of the industry.

Considerations

Among other findings, the study highlighted that developing a circular economy and responsible consumption would require a large-scale effort, enabled by government intervention to enforce compliance, holding organizations accountable through policy and regulation. Additionally, shifting paradigms around consumer culture and diverge from a throwaway lifestyle. Despite this important reflection, it was determined to be outside the scope of the project and was not included in the development of this toolkit.

In this regard, it is important to recognize that the scope and depth of this research were restricted by time and access to resources, as well as a limited network. Due to these circumstances, the final toolkit is presented as a conceptual instrument, and has not yet been tested in a real-life scenario or large-scale process. The next steps section details the intentions in this matter.

Additionally, relevant factors that could have determined the route and execution of the project were the background and number of experts interviewed. Although it was intended to achieve a balanced participation, the design category obtained a larger amount of participants, while the production category was quite limited. Nonetheless, the results and depth of responses were highly satisfactory and did not seem to negatively impact the quality of insights obtained.

Other important considerations were the range of the tools. These were developed with the goal of being highly practical and exploratory, without adding a sizable workload to the design process, therefore there is room for improving the content of each module for more technical results. As a result, it is intended to continue with this research project to improve the quality of tools and therefore, the outcomes of using the toolkit.

Next steps

The next steps for this project involve a deeper exploration of existing frameworks, testing the tools and analyzing their effectiveness. Similarly, the toolkit presented in this paper will be tested to identify potential areas for improvement from the opportunities that were to left aside for reasons of time and scope. Some of the potential features that were discovered and could be further explored include the creation of a library of sustainable materials to facilitate the comparison and sourcing of samples and feedstock, adding industry-specific strategy recommendations, doing a more exhaustive analysis of trade-offs of materials and circular strategies, and adding a foresight tool that allows to explore potential futures for different concepts and strategies.

Finally, the toolkit was designed to have physical elements such as card decks, which is why a printed version that contains a guidebook for ease of implementation will be developed.

Final thoughts

This Major Research Project, although an academic requirement for the degree of Master of Design in Strategic Foresight and Innovation at OCAD University, it is also a passion project for the author, motivated by the broad respect and love for the planet and its animals, human and non-human, as well as for the design and creation of objects that can create meaningful change.

Nevertheless, by pursuing a vision of a more socially responsible and sustainable industry, it is understood that in a circular economy the work of product design may not exist in the future, although it may not be a bad thing after all.

> **"I think that people will start looking at responsibility as a design process instead of just designing something because they like it, everything now is bigger than that."**
>
> – Interview participant, designer.

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Appendix A
Intervention Wheel

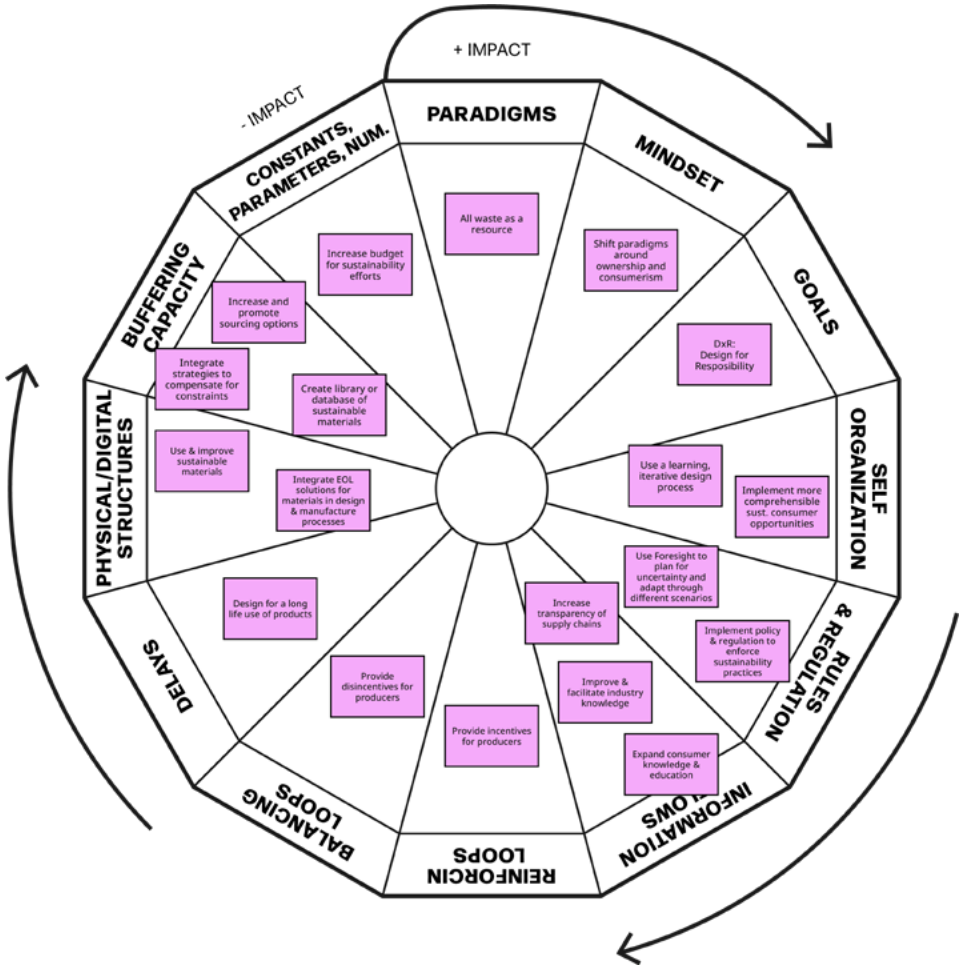

Figure 22: *Intervention Wheel adapted from the Systemic Design Toolkit (Van Ael et al., n.d)*

Circular Design Toolkit for Sustainable Futures

Thank you

M. Alejandra Farías Fornés