ROUNDING THE VERTICES

Toolkit for Circular Design

2022

CREATIVE NATURE HUB

Rounding the Vertices - Toolkit for Circular Design

Developed under the PhD Research project "Transition to Circular and Sustainable Economy through Design"

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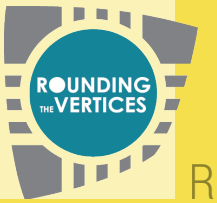
Content


ROUNDING
THE VERTICES

Introduction

Basis and rationale for the development of the design model for circular economy

The integration of sustainability principles in product development has been a concern of many professionals since the 70s, having, in a way, been significantly influenced by Vitor Papanek's book "Design for the real world" (Papanek, 1970), in which he calls into question the practice of design and the relationship of this professional activity with the environmental and social impacts and problems associated with product development. From green design to design for the circular economy, we have witnessed an evolution in design, in the concepts, practice and growth in complexity by integrating a larger scope of sustainability criteria (Vicente et al., 2012).

The circular economy, which can be considered as new step in the evolution of a necessary and fundamental demand for a more sustainable future, presents itself as a possible path in this direction. Because of this, the scientific, academic and business communities are highly motivated and committed to it. However, despite the numerous developments in terms of methodologies, practices, tools, funding opportunities, etc., there is still a huge gap between theory and practice (Camocho et al., 2019), between what is being developed in research and development projects and what is actually applied in practice, in new solutions that reach the market and the users.

It is essential to narrow this gap and provide designers, who have a fundamental and irrefutable role in the development of new products, sustainable services and systems, with interdisciplinary practices supported by synthetic methods, tools and guidelines. This will result in sustainable solutions, contributing to an environmentally efficient future, fair from a social point of view and that creates value and wealth for business and for the society.

In this sense, the "Rounding the vertices - design for circular economy" is a design method that supports this practice and integrates the project development perspective, the management of the design project and the perspective of the business. The method was developed to implement these considerations in early phases of the project with high innovation potential.

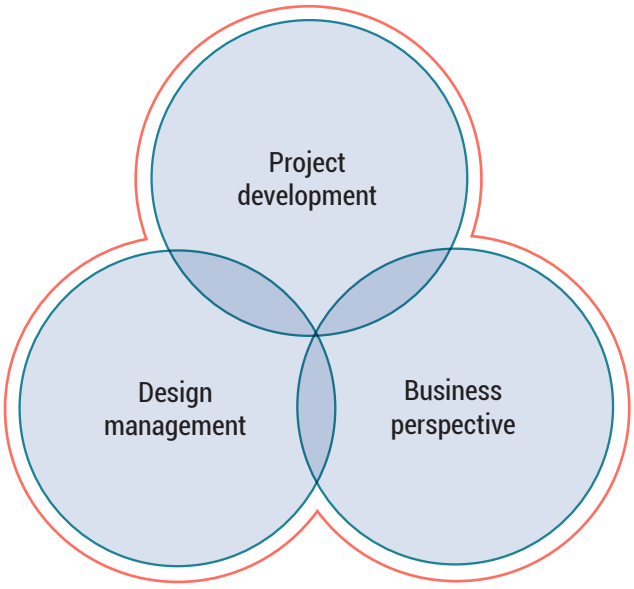


Figure 1: The 3 dimensions of the circular design model.

Rounding the vertices

The concept

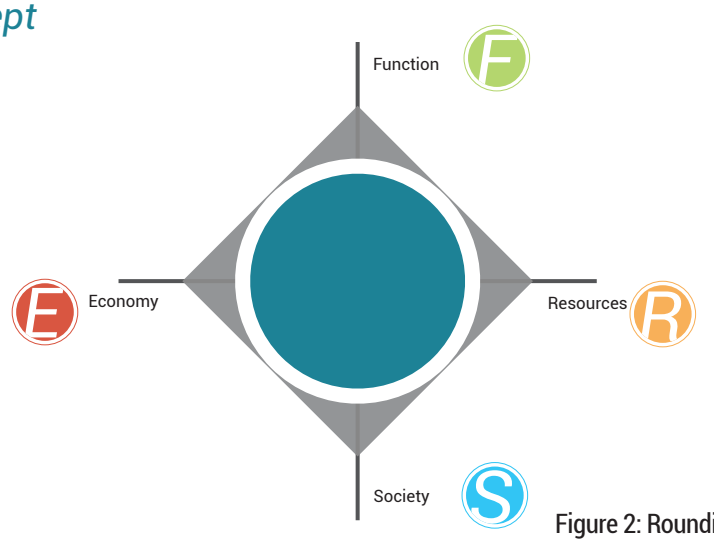


Figure 2: Rounding the vertices concept.

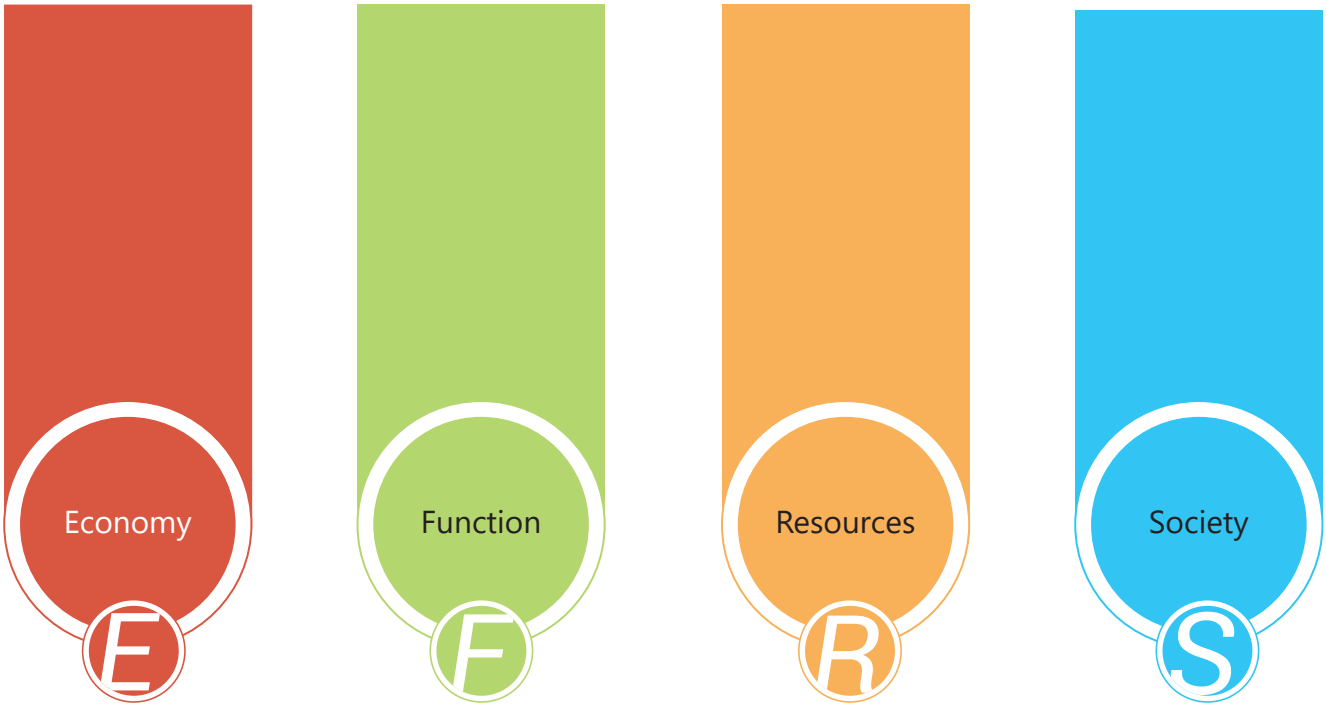
The transition from the linear economy to the circular economy relies on an improvement in the efficiency and effectiveness of the product and service systems. This transition, based on the maintenance of the materials in use in multiple cycles and the elimination of the production of waste through design options is seen as the potential path toward sustainability.

The Rounding the vertices is a design concept that aims to illustrate the design practice towards circularity that is based on that the transition from a square shape (an analogy to the current linear approach) to a circular shape by increasing the performance of products and services system requires less area. This means that to achieve circularity, we need to improve the system by reducing the consumption of material and energy as well as improving the efficiency of the life cycle.

The method is based on the improvement of the efficiency of an entire product or service system in a holistic approach, operating at various levels and improving the product's sustainability and the relation to the needs of the users. Only a concerted approach achieves an effective improvement, taking into account the implications of the design process in the various dimensions as well as the tradeoffs that result from the development process.

In the concept, the improvements in the transition to circularity are demonstrated by improvements in the 4 vertices, each one referring to a dimension that must be considered in a holistic and harmonized approach, thus resulting in a new shape and ideally reaching the circle that represents the achievment of circular solutions.

The four dimensions



The aim is to optimize the economic aspects related to the system creating sustainable value and wealth for all actors in the value chain through the design approaches and measures adopted in the project

The project should put into question the current solutions and rethink the system focusing on the function. Through a function approach, the design team has more levels of freedom to innovate and attain higher circularity and sustainability performance and can lead to out-of-the-box solutions.

The resources needed to fulfil the function should be optimized. The optimization and the efficiency of the consumption of materials, such as energy and water, in the product or service systems has the potential to improve the circularity and sustainability aspects of the systems.

Design for a better society should be also the motto for the design project. The creation and promotion of welfare, safety and good working conditions are an added value for the society that can be achieved through design.

Circular design development model

Development of the Circular Design Model and toolkit

Aiming to support and promote the design practice, the Rounding the vertices design model was developed. Built upon the results of the research, review, analysis of strategies, tools and methods, and other relevant information collected and analyzed, the structure of the model (figure 3) derives from the six main stages of a design project and relates the activities of the process with three levels that complement each other resulting in a robust model to support the design practice towards circularity and sustainability:

- The **Project management level** to support an efficient integration of circularity in the different phases and aspects of Design management
- The **Business level** to align the development with the strategy and considerations of the business, promoting the efficiency and sustainability of the system.
- The **Development level**, to support the practice and the integration of the circularity and sustainability considerations, methods and tools in the development of new and innovative products, services and systems.

The model establishes the relation of the design thinking process with the goals of the circular econmy to define how the resources can guide the design process to promote sustainability and circularity in processes.

The strategy for the design practice within a circular economy is supported by the four tools that can be applied by practitioners in their activity to develop innovative and sustainable circular solutions. The translation of the model into the practice is done through the design for circularity and sustainability toolkit.

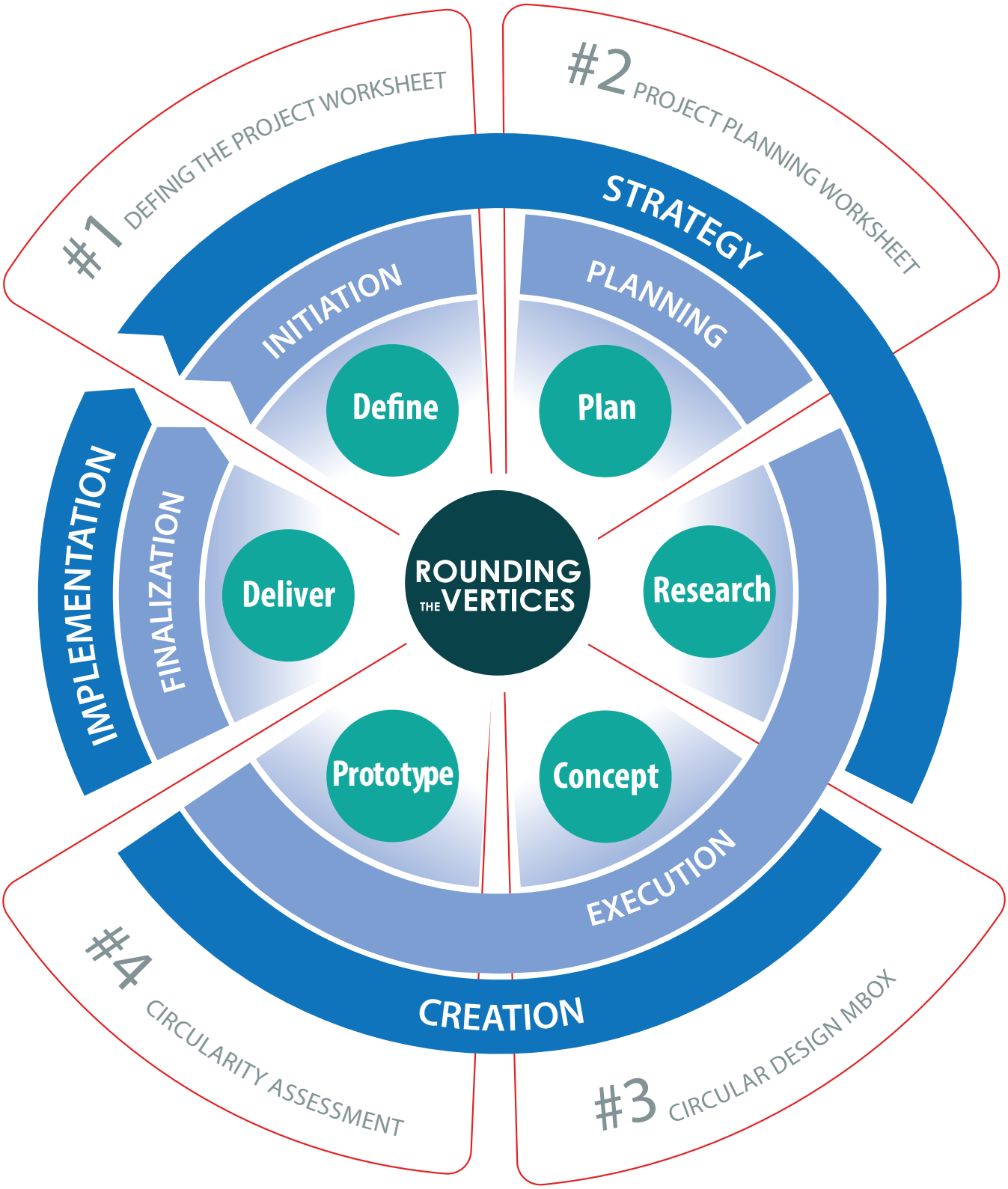
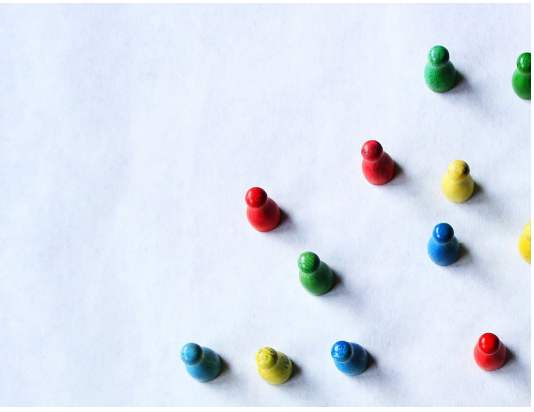


Figure 3: Rounding the vertices design model

Toolkit overview

The Rounding the vertices circular design toolkit is composed of a set of four tools that can support the design practice towards circularity and sustainability.

The tools are used according to the design process and are interlinked in order to guide the design process and help the design and development teams in the definition and planning of the project, identification of improvement measures and ideas to develop new solutions, and the validation and demonstration of the circularity performance of the design process undertaken and the results of the project.



#1 Definig the project worksheet

The first tool is focused on supporting the initiation of the project and the definition of what needs to be done. The goal in this phase is to systematize the process of the initial information, based on the strategic approach led by the business, and make sure that the development team always gets the information needed and guidance for the project development.
The result of the tool is a systematized definition of the strategy, goals and characteristics for the circular design project structured to improve the efficiency of the solutions according to the Function, Resources, Economy and Social levels

#2 Project planning worksheet

The project Planning worksheet helps the team in defining the work to be done and creates the roadmap and structure to follow within the project to meet the objectives defined previously.
The tool organizes the project through the identification of the activities to be held, the resources needed and the duration of the task within the project.

#3 Circular design Mbox

The circular design Mbox combines the concept of the morphological box tool, widely used by designers in the identification of design solutions, with 10 design principles for circularity and sustainability.
With the support of the tool, design teams can implement the design principles in a systematized approach, leading to the identification and creation of innovative and circular solutions for product and service development within the project.

#4 Circularity Assessment tool

The tool performs a qualitative assessment of the circular approach in the design project based on the four levels to round the vertices (Function, Resources, Economy and Social levels), based on the assessment of the performance of the project according to the 10 circular design principles, and their impact in the transition to a more circular and sustainable solution.

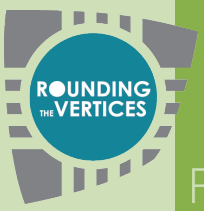
How to use the toolkit

The toolkit provides four tools to systematize the integration of circularity aspects in the design process. The tools were developed to be used to support the four stages of the design process: (1) The strategic definition of the project, (2) the management of the project, (3) the creation of new concepts and (4) the assessment of the design process and its results.

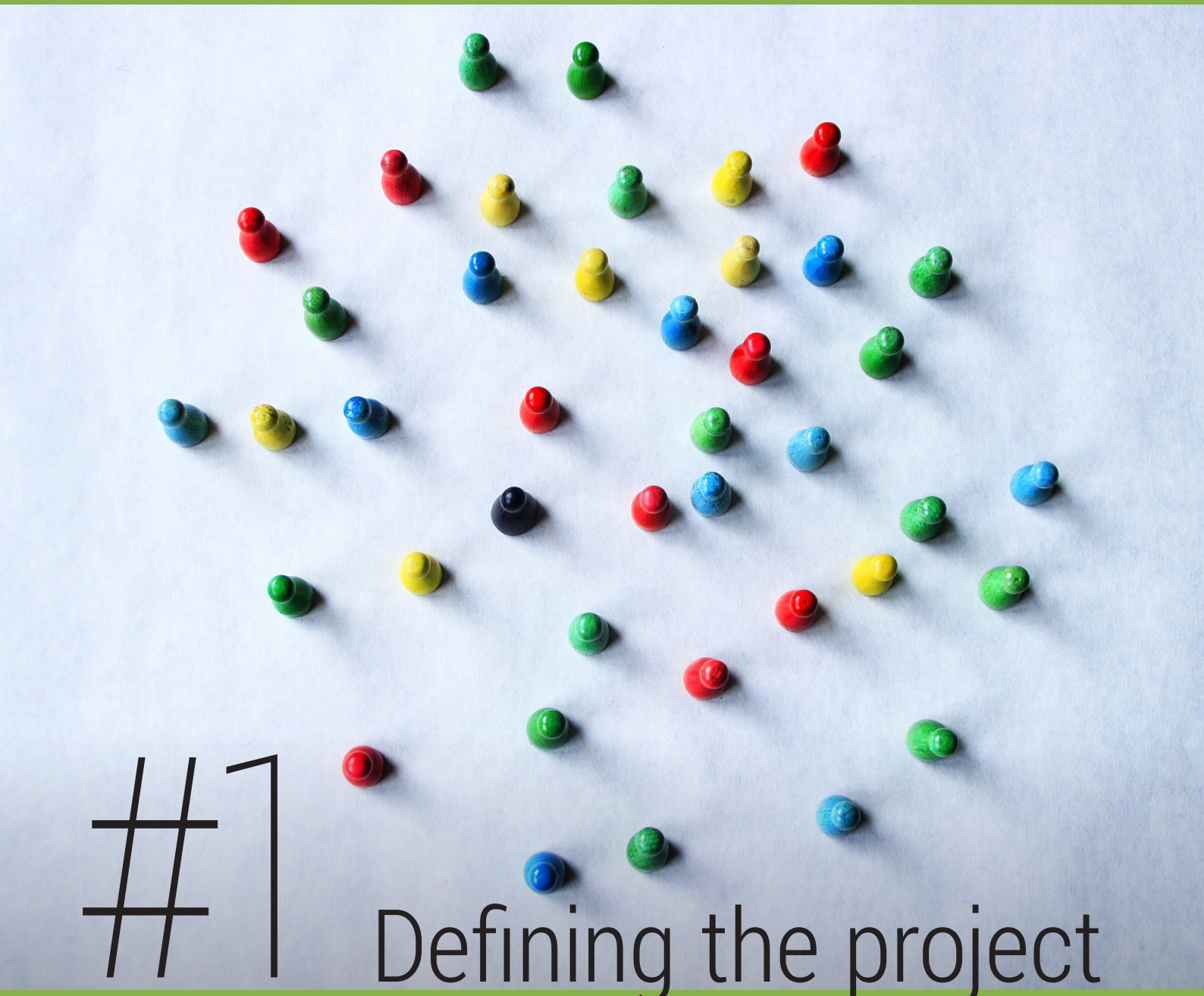
There are two versions of the tools that should be used according to the needs and experience of the design teams.

The e-book version – a comprehensive resource with the theoretical content. The 3 initial tools are composed by a set of worksheets in which the design team needs to reflect and fill in the tables. The assessment tool, due to the calculation features, is to be used only in the excel version. In the e-book, an explanation of this tool is presented.

Excel based tools - These versions of the tools were developed in excel so that the design team can fill in the spreadsheets in a more systematized way. These include calculations and features to simplify the filling-in process, however, it does have the limitations of the excel software.



ROUNDING THE VERTICES



#1 Defining the project Worksheet

This worksheet helps the in the definition of the strategy for the development of products and services that meet the needs on the entire system.

Planning the business strategy towards project development

Defining the needs of the project

Identify the current needs and motivations of your business for the development of a circular economy design project

Defining the needs of the project supports the definition of the problem that the project will address. In this stage, the design and development team should identify why there is the need to develop a new design project with a circular economy approach, what are the motivations for the company, what moves the company towards circularity and what are the known barriers for the project.

Why does your business need to enrol in a design for a circular economy project?	What are the company's motivations for a CE design project?	What are the known barriers for a CE design project?

Defining the market

Identify the current and potential market for the business and their sustainability and circularity concerns

Based on market analysis, in this stage, the team must define the market for the product or service under development. This supports the guidance and definition of the project objectives and boundaries.

In this worksheet, the design team must identify the current market, the market that is already covered by the company and the current products, the potential market that can be achieved with the development of the new product and the opportunities for the project.

In this stage, the team must also understand what the market is demanding in terms of sustainability and circularity and how the business can meet these needs.

Identify the opportunities

Identify potential markets for the business

What are the barriers of your business to meet the needs of the market?

What are the sustainability and circular demands of the market?

Defining the business model

Describe the current business model

The business models define how the company plans to make money with its products or services. It outlines the structure and boundaries of the system in which the company operates and the relation with customers or users and the market.

Circular and sustainable business models focus on the value generated of a product or a service and try to capture value throughout its life, aiming to close resource loops and minimize the impacts over the life cycle.

In this stage, the design team must understand the current business model and how the company can innovate and increase its value.

Describe the current business model, determine how value is created and define the structure of the business	Identify and describe the main sustainability and circularity aspects of your business

New business models

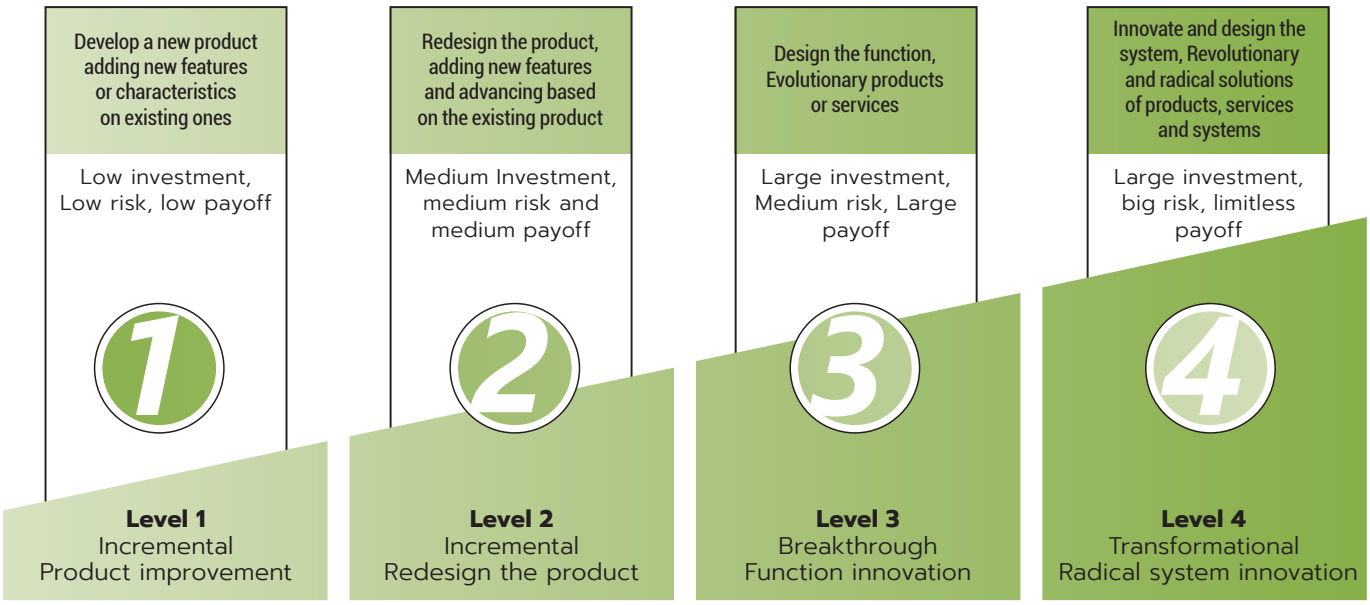
Does the company have the flexibility to adopt different business models? If yes, analyse the following circular business models and identify the potential of each model for your case.

Circular supplies	The circular supplies business model is particularly relevant for companies dealing with scarce commodities, in which scarce resources are replaced with fully renewable, recyclable or biodegradable resource inputs.	
Resource recovery	The resource recovery business model leverages technological innovations and capabilities to recover and reuse resource outputs that eliminates material leakage and maximizes economic value.	
Product life extension	The product life extension model helps companies to extend the lifecycle of their products and assets to ensure they remain economically useful. Material that otherwise would be wasted is maintained or even improved, such as through remanufacturing, repairing, upgrading or re-marketing.	
Sharing models	The sharing platform model is centered on the sharing of products and assets that have a low ownership or use rate. Companies that leverage this model can maximize the use of the products they sell, enhance productivity and value creation.	
Dematerialization from product to services	Through the product as a service BM, customers use products through a lease or pay-for-use arrangement versus the conventional buy-to-own approach. This model is attractive for companies with high operational costs and ability to manage maintenance of that service and recapture residual value at the end of life.	
Stewardship role in stakeholders engagement	Proactively engaging stakeholders to ensure their long-term health and well-being and promotion of co-development, co-creation and synergies	
Encourage sufficiency and efficiency	Solutions that seek to reduce consumption and production by eliminating superfluous features and improving the efficiently through design	
Develop Scale-up solutions	Delivering sustainable solutions on a large scale to maximise benefits for society and the environment.	

Sources: //www.greenbiz.com/article/5-business-models-put-circular-economy-work A literature and practice review to develop sustainable business model archetypes- N.M.P. Bocken*, S.W. Short, P. Rana, S. Evans University, adapted

Innovation level

The project can be oriented for a specific level of innovation according to the objectives and strategy of the company and the design team, however, the level of innovation has a direct relationship between the financial resources needed, the development time, the know-how, human resources, technologies, etc. In this step analyze the four innovation levels and indicate the level expected for the project.



Source: https://gbr.pepperdine.edu/2010/10/the-four-levels-of-innovation/

Figure 4: Innovation levels

Which is the innovation goal for your project? Level 1 ☐ Level 2 ☐ Level 3 ☐ Level 4 ☐

Justify your selection

Project definition (1)

Defining the strategy, goals and characteristics for the circular design project.

Based on the previous analysis, this worksheet aims to systematize and define the project under development.
This document will support the team in the definition of the project and will guide the design project.

What product or service has to be developed? Or what is the function or problem addressed?	Define the product, service, function or problem that will be addressed in the project	
Circularity and sustainability goals for the project?	Indicate the goals that will guide the project	
Motivations	Indicate the main motivations for the project	
Target group	Indicate for whom the product or service will be developed. Indicate the main characteristics of the target group	
Business model	Indicate the business model expected for the solution to be developed.	

Project definition (2)

Innovation Level	Indicate what is expected in terms of innovation for the new solutions according with the context in which the new project is based	
Resources available	Indicate the resources that are available for the project (Human resources, technological resources, budget, etc)	
Project team	Identify the project team (internal or external) and describe their role in the project	
Time available to develop the project	Indicate the expected or available time to develop the project	

Rounding the vertices

Define the strategy for the project aiming to improve the efficiency in each area.

Having in mind the project definition and the requirements identified, the design and development team should indicate in this stage which are the objectives and the strategy towards the four levels of the rounding the vertices concepts.
Here, the team will indicate how to improve the function of the product or service, how to improve the efficiency in term of resources used within the life cycle, and how to improve the economic and social aspects of the product or service system.

Function

How can the function of the product be improved?

Physical resources

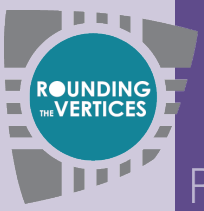
How can the resources efficiency be improved?

Economic resources

How can the costs and revenues be improved?

Social dimension

How can the project improve society?



ROUNDING THE VERTICES

#2 Project Planning Worksheet

This worksheet helps design managers and design team in the planning and management of design projects for a circular economy.

Planning the design project towards circularity

Planning of the project

Defining the scope and deliverables for the project

Define the scope of the project and define the deliverables that are planned for the project.

Define the boundaries of the project.

Indicate the scope of the project under development and describe what should result from the project.

(eg. Tecnical drawings, renderings, mock-ups, prototypes,etc)

Planning of the project

Identifying the stakeholders for the project

Indicate the main stakeholders for the project and what will be their involvement and importance in the project.

STAKEHOLDER	PURPOSE	LEVEL OF IMPORTANCE
Insert the stakholder name (or type)	What will be the involvement of the stakeholder. Why do we need to involve this stakeholder?	Select the level of importance of each stakeholder (1 - low, 10 - High)

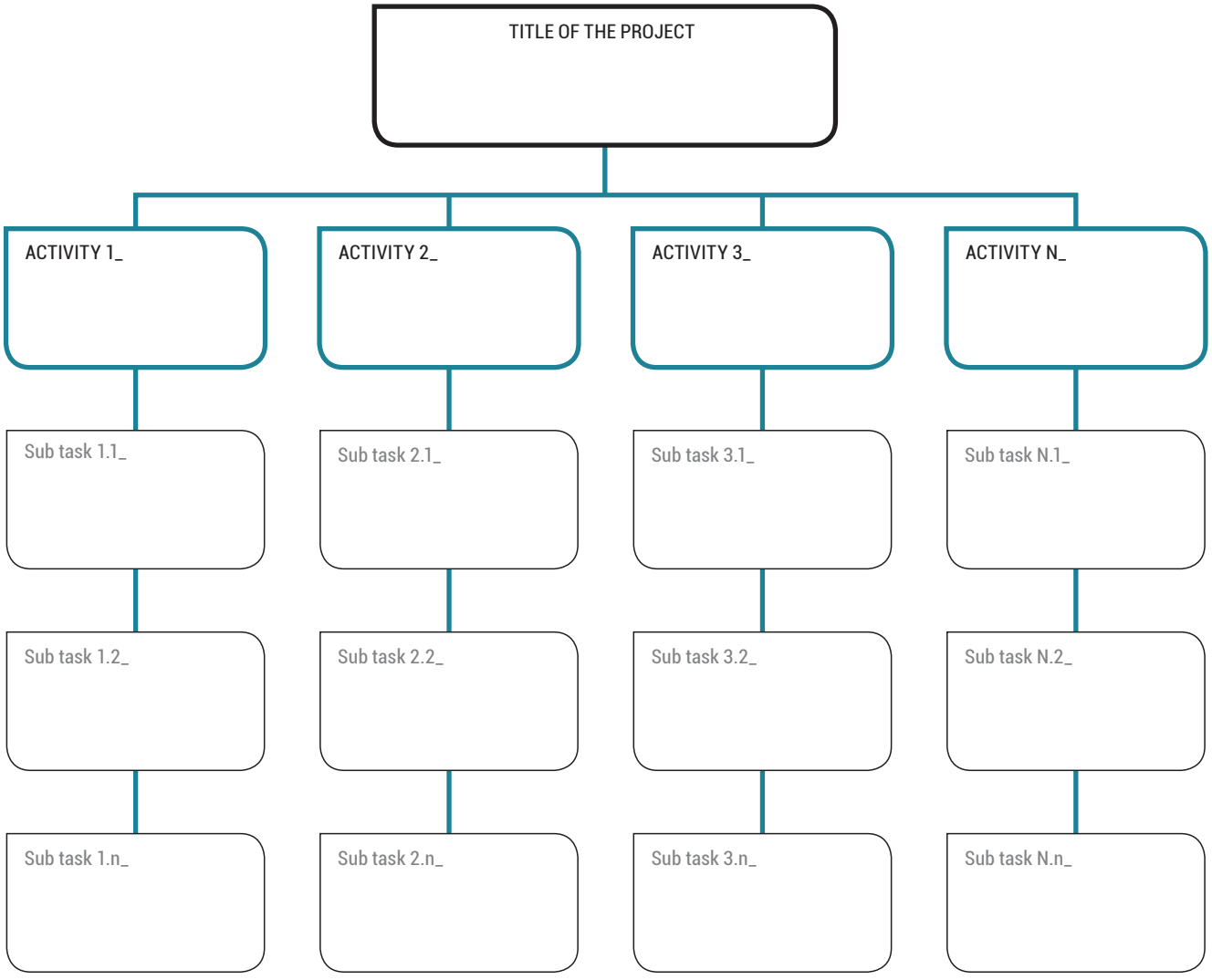
Source: CE Value Chains tool, KATCH_e

Planning of the project

Defining the activities and taks for the project

This worksheet helps design managers and design teams in the planning and management of design projects for a circular economy.

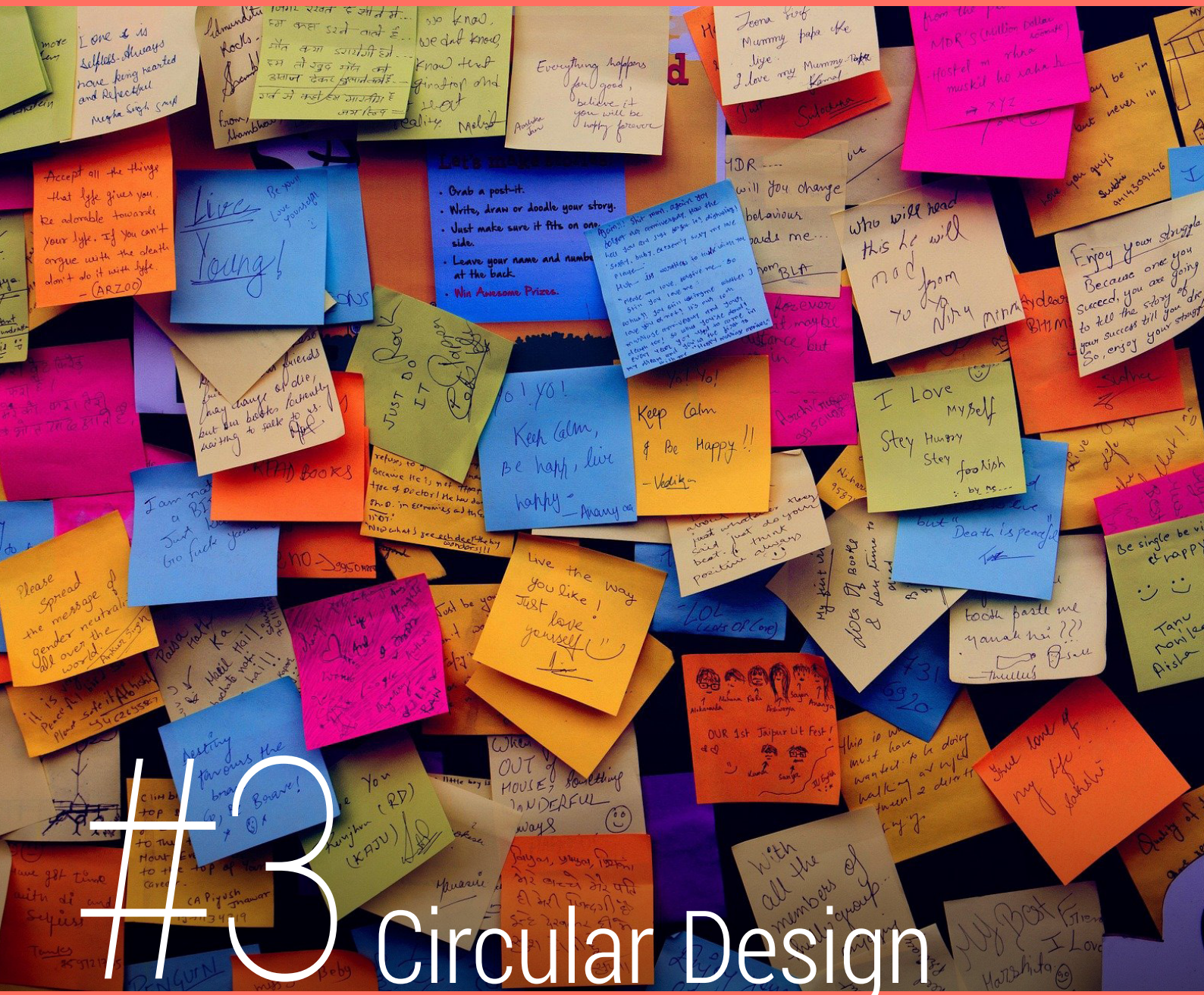
In this sheet, the management team should identify the main activities and their related subtasks in order to develop the circular design project. These must reflect the needs identified and the goals of the current project. The number of activities and sub tasks should be adapted to the specifications of the project.



In this step, the management team should identify the resources and time needed to perform the main activities and their related subtasks.

TITLE OF THE PROJECT

ACTIVITY	SUB TASKS	RESOURCES	DURATION
Indicate the activities defined for the project	Indicate the sub tasks defined for the project	Which resources are needed to fulfil the task?	How much time is needed to perform the task?
ACTIVITY 01_	Sub task 1.1_	Resources_	Estimation of time_
	Sub task 1.2_	Resources_	Estimation of time_
	Sub task 1.3_	Resources_	Estimation of time_
ACTIVITY 02_	Sub task 2.1_	Resources_	Estimation of time_
	Sub task 2.2_	Resources_	Estimation of time_
	Sub task 2.3_	Resources_	Estimation of time_
ACTIVITY N_	Sub task n.1_	Resources_	Estimation of time_
	Sub task n.2_	Resources_	Estimation of time_
	Sub task n.3_	Resources_	Estimation of time_



#3 Circular Design Mbox

This worksheet helps the design teams in the identification of ideas for circular product development

Development of new concepts

Circular Design Mbox

10 principles to support the design process towards more sustainable and circular products and services

In the design practice towards circular economy and sustainability, with the objective of creating innovative solutions for products and services, the design team can apply a set of principles that support and systematize the process.

The 10 principles that compose the Rounding the vertices approach were developed based on a research process in which several methodologies, tools and different approaches were analysed.

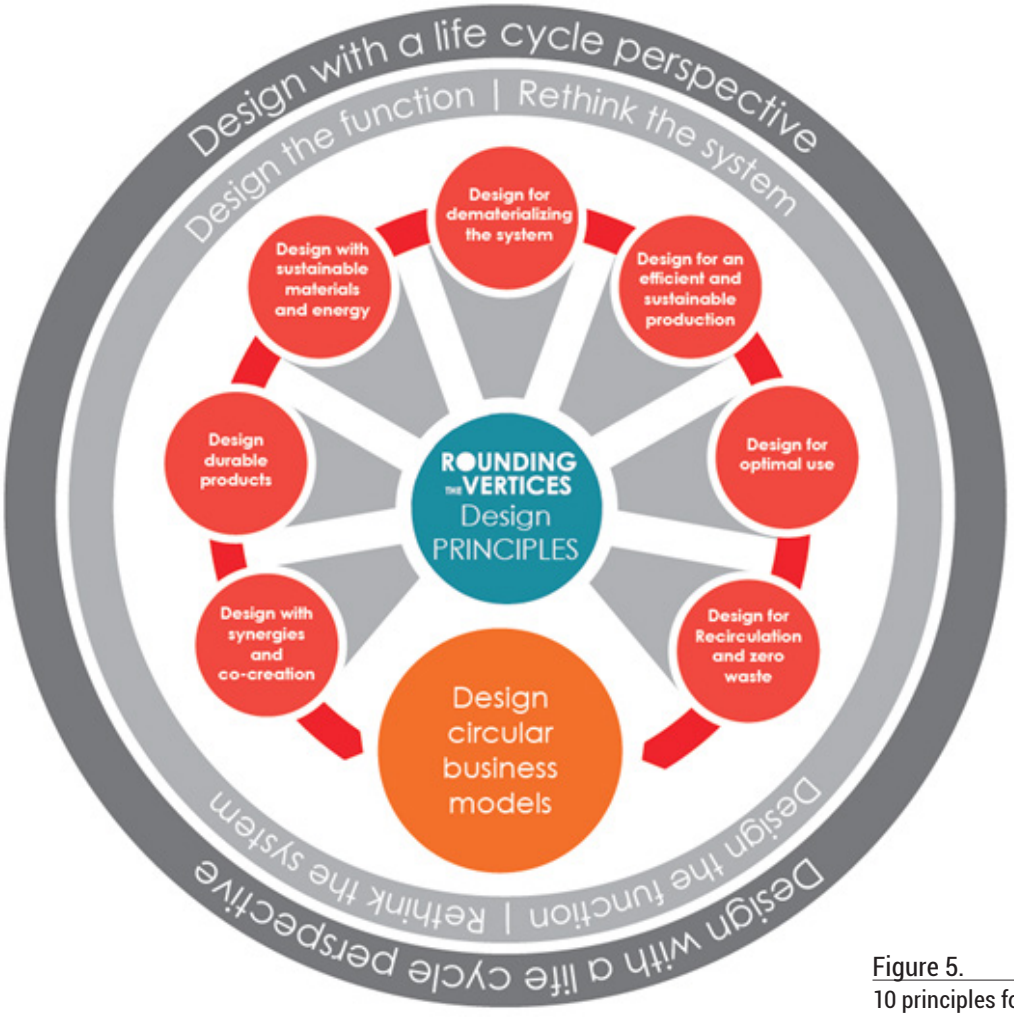


Figure 5.
10 principles for Circular Design

The principles, developed for designers, are project-oriented and through their analysis and implementation, the design teams can, in a holist approach, identify design opportunities that result in more circular and sustainable solutions.

The first two principles, **Design with a Life Cycle Perspective** and **Design the function/ Rethink the system** (outer rings in the figure 5), are seen as an umbrella principle that supports and validates the design process.

Considering the **life cycle perspective** is fundamental in the development of circular and sustainable products or services and to provide decision-makers with information on the impacts (environmental, economic and social) of different choices taking into account the positive and negative impacts of the entire life cycle (KATCH_e BOOK).

This approach allows a reasoned consideration of the trade-offs between different environmental aspects throughout all life cycle stages (IEC 62430:2019)

Life cycle perspective means the consideration of environmental aspects relevant to a product or service during its entire life cycle. This implies considering the interlinked stages that compose the life cycle (ISO 14006:2020). Within the design process, the life cycle perspective has as its main objective the reduction of the overall adverse environmental impacts of the product in parallel with the usual development aspects such as safety, quality, functionality, ergonomics, aesthetics, etc (IEC 62430:2019)

Without a life cycle perspective, there is no guarantee that the design team and the solutions attained in the project are really reducing the impacts of the product or the service. Through a life cycle analysis (quantitative or qualitative, depending on the objectives, the project, the resources, time, etc), the team, can validate the solutions and can communicate them to the stakeholders.

Design the function/Rethink the system aims to understand the function and the needs of the users and identify new opportunities to fulfil the needs in a more circular and sustainable way. Making something more circular requires rethinking the process, rethinking the system and the function of the product.

At the beginning of the project, the design team must put into question the function of the product. Does the user need the product? Does the product fulfil the function in an efficient way? Are there other ways to fulfill the function?

By having a function approach, there is more potential to innovate, to achieve out-of-the-box solutions, and new ways to attain a solution with an improved circularity and sustainability profile.

The following principles (red circles in figure 5.), are operational principles. These provide different aspects to consider in the design and development process.

DESIGN WITH SYNERGIES AND CO-CREATION focus on exploring the potential to establish collaborations in the design process and the product or service system

DESIGN DURABLE PRODUCTS, a principle to ensure a long utilization period of products, maintaining its function and service over a longer period of time.

DESIGN WITH SUSTAINABLE MATERIALS AND ENERGY focusing on the conscious selection of more efficient inputs within the entire life cycle of the product.

DESIGN FOR DEMATERIALIZING THE SYSTEM, a principle in which the needs of the users are fulfilled with more dematerialized solutions and product-services or services solutions

DESIGN FOR AN EFFICIENT AND SUSTAINABLE PRODUCTION, based on the optimization of the production process through design solutions.

DESIGN FOR OPTIMAL USE, aiming to optimize the relation of the product and the user

DESIGN FOR RECIRCULATION AND ZERO WASTE, aiming to close the loop by developing solutions to close the material cycles and eliminate the production of waste in the life cycle.

The final principle is the **DESIGN OF CIRCULAR BUSINESS MODELS**, (orange circle in figure 2.). This principle is the last one since it aggregates the results of the application of the previous principles. In the transition from the linear economy to a circular economy. We need to rethink the business models in order to achieve long-lasting and effective circular and sustainable solutions.

The circular design morphological box combines the concept of the morphological box tool, widely used by designers in the identification of design solutions, with the 10 design principles for circularity and sustainability.

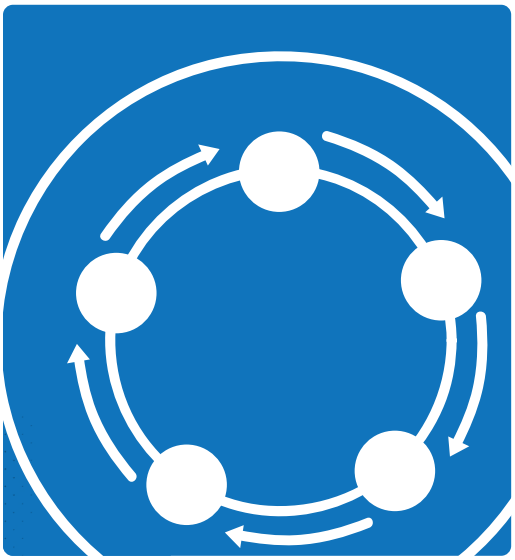
The 10 principles that compose the Rounding the vertices approach were developed based on a research process in which several methodologies, tools and different approaches were analysed.

These principles, developed for designers, are project-oriented and through their analysis and implementation, the design teams can, in a holist approach, identify design opportunities that result in more circular and sustainable solutions.

With the support of the tool, design teams can implement the design principles in a systematized approach, leading to innovative and circular solutions for product and service development.

In the next pages, the principles are explained and some ideas on what to consider in the design phase are presented. These should support the design teams in the identification of opportunities for the project and their application can result in new products and services.

1. Design with a Life Cycle Perspective



It is estimated that over 80% of all product-related environmental impacts are determined in the design phase. Therefore, it is crucial to design with a life cycle perspective in order to minimize, or ideally, eliminate impacts considering the entire life cycle of products and services.

The design and development teams should ensure that circular economy aspects are integrated into product design and development early in the development process with the aim of improving circularity and reducing impacts throughout the entire life cycle of the product or services (BS 8001), while still taking into account other design aspects such as safety, quality, ergonomics, aesthetics, and also, considering the trade-offs and compromises between different environmental aspects and the attained solutions (IEC 62430 2019).

Designing for the circular economy and aiming for a more effective and optimized management of resources across the life cycle with a holistic perspective should lead to a positive impact on the natural environment and society (BS 8001). Therefore, top management and decision-makers should ensure that strategies are planned, implemented and maintained, considering all stages in the life cycle of a product (ISO 14006:2020), through design.

If the reference product was developed with a life cycle perspective, please describe how it was considered.	
Indicate the objectives/gaps for your project in regard to life cycle perspective.	

What to consider in the design phase

1.1 Consider all life cycle phases

The design team, when designing with a circularity and sustainability focus, must adopt a holistic approach and consider the entire life cycle of the product or service in the process, considering all *"Consecutive and interlinked stages of a product (or service) system, from the raw material acquisition or generation from natural resources to final disposal. (...) including the acquisition of raw materials, design, production, transportation/ delivery, use, end-of-life treatment and final disposal."* (ISO 14001)

1.2 Analise the impacts in each phase/ Conduct LCA studies

In order to guide the design process towards the minimization or elimination of impacts in the life cycle of products or services, the design team must have knowledge about the environmental profile of the products. In this regard, a life cycle assessment is fundamental to have a clear overview and perception of the impacts in each stage.
For the Identification and evaluation of environmental aspects, the team should establish, implement and maintain a process to identify and evaluate product-related environmental aspects and impacts throughout the life cycle. This assessment, according to the objectives and resources of the project can have a qualitative or quantitative evaluation and prioritization of the environmental aspects, however, where feasible, the quantitative approach is encouraged (IEC 62430:2019).
By conduction LCA studies, the team can also identify opportunities to improve the environmental performance of products acting in several stages in their life cycle, support the information to decision-makers for strategic planning, priority setting, product or process design or redesign, marketing purposes, or other (ISO/FDIS 14040).

1.3 Avoid the transference of impacts for other phases of the life cycle

The life cycle approach, through an overview of the impacts in all stages, can avoid the transference of impacts from one stage to another, which is a common result of projects developed without a life cycle approach.
The transference of impacts can occur from one stage to another, from one region to another or even from one impact category to another. For example, one solution can reduce the quantity of a material used in the product, however, for this reduction, the material was substituted by a different material, produced in a far location, resulting in a material with a higher embodied energy.

	DESCRIBE YOUR PRODUCT ACCORDING TO THE LIFE CYCLE STAGES	IDENTIFY THE MAIN IMPACTS RELATED TO THE STAGE
RESOURCES	Identify and describe the resources used in your product, considering materials, energy and water	Identify the impacts related to the resources used in your product
PRODUCTION	Describe the production of the product	Identify the main impacts related to the production
DISTRIBUCTION	Describe how the product is distributed	Identify the main impacts related to the distribuction
USE	Describe how the product is used, including the use, consumables, maintenance, repair, etc	Identify the main impacts related to the use of the product
END OF FUNCTIONAL LIFE	Describe what hapens after the functional use of the product.	Identify the main impacts related to the end of funcional life of the product
Explain how the impacts were identified	In this field describe the source of the inputs. Are they based on a Life cycle analisys? Qualitative or quantitative?	

2. Design the Function /Rethink the System

The circular economy can be characterized by a Rethink approach. To make something more circular requires a rethinking process. (Morseletto, 2020)

Rethinking the system and the function of the product is a way to look at your product and envision sustainable alternatives by thinking outside the box and have new approaches and perspectives for the product and the system which are translated into new or reshaped objectives for the design project.

Rethinking allows an identification of alternative design solutions to solve the problem (BS8001). In a circular design approach, the focus should be on the outcome to fulfil a specific need. The key is to design the most sustainable way of producing that outcome. Outcome-driven thinking places the focus on the function the user needs and not on the solutions of how to produce or deliver the offering (Niinimäki & Hassi 2011).

Rethinking is about developing new ideas and solutions to provide certain product functions in line with the needs of the users, including the re-elaboration/reconceptualisation of ideas, dynamics, processes, concepts, uses, and post uses of a product (Morseletto, 2020).

Indicate the current situation. Explain briefly the funtion of your product or service	
Indicate the objectives/gaps for your project according to the function of your product	

What to consider in the design phase

2.1 Question the function

In a circular economy approach, aiming to close the material and component loops in a sustainable way, the design team should put into question the function of the product. Perhaps, the users do not need a product at all, or their needs can be fulfilled with a totally different solution. The circular economy needs an out-of-the-box approach in attaining innovative solutions.

By approaching the process through the function, the potential to innovate is higher. In this regard, a function analysis, which is a fundamental phase in the value analysis methodology which consists of a systematic process to describe the product through its function, can be implemented. The product is not considered as a specific solution with a group of components, but through a set of functions that will satisfy the needs of the user (Justina et al., 2007), it supports a creative problem-solving approach by moving the focus away from the expected solution and placing the focus on the required performance or need (valueanalysis.ca.)

2.2 Develop new concepts

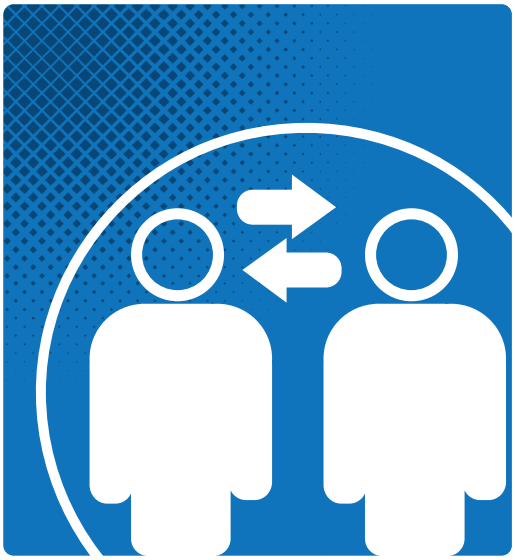
Most design projects are developed with a lower innovation level, focusing mainly on product improvements or product redesign. With this approach, the new solutions attained can improve the systems by developing better products with lower environmental impacts, however, disruptive solutions with a higher potential for circular economy and sustainability are almost impossible to occur.

To have an effective approach and reach a higher level of innovation and sustainability, the design teams must innovate with alternative ways to fulfil the functions and the needs of the users.

It is recommended to start by thinking "out of the box" and develop new concepts (Rocha et al, 2015) and new solutions that rethink the entire system. Not only the product itself but the entire context in which the product operates.

	WHAT IS THE FUNCTION OF THE PRODUCT?	
FUNCTION	Describe the function without describing the product	
FOR REFLECTION	DOES THE USER NEED A PHYSICAL PRODUCT?	
DEVELOP NEW CONCEPTS	Identify alternative ways to fulfil the funcion	

3. Design with Synergies and Co-creation



The design practice has been evolving. This evolution, from a user-centered approach to co-designing, is changing the roles of the designer, the researcher and the users (Elizabeth, 2008).

In design for a circular economy, as a new step in the design evolution, changes are needed in the field of design and design education towards disruptive innovations for transformation, intelligent systems, open design and others, and a new views and approaches on design processes. The participation of the stakeholders in the process is being promoted, especially through collaborative forms like open design, co-creation and participatory design (Hummels, 2012), and the establishment of synergies in the value chain.

Some authors even consider that without collaboration initiatives, it is unlikely that an organization can achieve a successful and substantial progress in the transition to a more circular and sustainable economy (BS 8001).

Indicate the current situation. Explain how synergies and co-creation are related to reference product or reference situation	
Indicate the objectives/gaps for your project regarding synergies and co-creation	

What to consider in the design phase

3.1 Collaborate and co-design

The design practice for circular economy and sustainability should promote the collaboration of designers and other professionals in order to attain the needs of the projects along the life cycle. Building teams to strengthen knowledge and expertise, building relationships with stakeholders (Circular design guide), providing space for customers and users, to be actively involved in design and development of products and services (Marlien, 2019) will influence the innovation and the identification of new ideas with a higher potential of success.

Adopting co-creation initiatives into the design practice will cause several changes to occur in the process. It will change the design practice, what is designed, and who designs (Elizabeth et al., 2008). Co-designing will promote a close collaboration between stakeholders in the design development process together with other professionals with other skills (Elizabeth et al., 2008) allowing to explore the potential of each actor, creating value in the process, reducing risks, costs and increase the potential for success.

3.2 Synergies

In a circular economy, it is advocated to optimize resources, optimise the material flows and create alternative and efficient ways of production and consumption focusing on maintaining materials and components in use without the generation of waste. These goals, to be effective and implemented in practice through design, must consider and explore the potential synergies that can be created in the value chain.

The creation of synergies which promote collaboration throughout the supply chain will increase transparency and create a joint value (Circle economy)

3.3 Industrial Symbiosis

The design of new products, services, or systems must consider the potential for the establishment of industrial symbiosis solutions, in which the waste or by-products of an industry or industrial process becomes the raw materials for another. The application of this concept allows a more sustainable use of resources and contributes to the creation of a circular and sustainable economy (ec.europa.eu 2018).

This process-orientated, approach focused on using residual outputs from one process as feedstock for another process must consider the geographical proximity of businesses (Bocken et al., 2016) in order to be efficient and add value for all actors involved in the process or system.

The benefits for the business network can have significant impacts, such as the reduction in overall operating cost and risks, the establishment of reliable alliances, increase the trust in partnerships, joint innovation processes, sharing of assets, services, etc.

	WHICH SYNERGIES AND CO-CREATION ACTIVITIES CAN BE IMPLEMENTED IN YOUR PROJECT?		
	COLLABORATE AND CO-DESIGN	SYNERGIES	INDUSTRIAL SYMBIOSIS
	Identify ideas for collaboration and co-design development within the project	Identify potential synergies that can support the project and the product or service developed	Identify potential industrial symbiosis related to the product and the company
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4. Design Durable Products

Designing durable products with a long-life is concerned with ensuring a long utilization period of products, maintaining its function and service over a longer period of time without loss of performance (Rocha et al., 2019), aims for a maximum potential lifetime of a product, component or material to perform a required function under intended conditions of use and maintenance before it becomes obsolete because it can't fulfil its function (BS8001).

New products should be designed to be durable for a long lifetime through the integration of solutions and features that facilitate easy repair, particularly by third parties, (BS8001), maintenance, upgrade, etc. The design team must also select effective materials and components that guarantee the durability of the product. Designing for durability is mainly focused on the physical durability, by the development of products that can take the wear and tear without breaking down, attained by design solutions and effective material selection, by designing reliable products that will operate throughout a specified period without (Bocken et al., 2016), and by developing product life extension features concerned with an increase in the use period of products, through maintenance, repair and upgrading characteristics defined at the design stage (Rocha et al., 2019).

The objective of this principle is to extend the technical, aesthetic and emotional lifetime of the product so that it will be used for as long as possible. While this strategy may seem unattractive for companies because they would "sell less", it can be interesting and competitive for certain types of products and market segments where high quality and durability are a strong sales argument (Rocha et al., 2015).

Developing durable products, that are used and maintained for longer is the counter-strategy to the implanted programmed obsolescence, which is linked to techniques and solutions by which an "organization seeks to deliberately limit product lifetime in order to increase replacement rate" (BS 8001).

Indicate the current situation. Explain how the reference product of reference situation is performing regarding durability	
Indicate the objectives/gaps for your project in terms of durability	

What to consider in the design phase

4.1 Quality of materials

The selection of the more suitable materials to fulfil the needs of the product and their function is crucial in design for the circular economy. The adequate material will promote the durability of the product without creating additional needs in the life cycle of the product.

The quality of the materials in the product should be selected according to the function, considering the implications and trade-offs in the life cycle of the product. For example, the selection of a high grade and high-quality material for a product that has a short life and will be recycled after a short period of time is not a good option.

4.2 Reparability

Durable products that can be used for long periods of time should rely on the possibility of being repaired easily and at an affordable cost for the user.

In the design phase, the design team should include features to promote and facilitate the reparability of the product. Features like a design for easy disassembly, the use of standard components, diagnosis systems, repair information, repair services, etc, should be developed.

4.3 Maintenance

Easy and affordable maintenance of the product can have a high impact on durability of a product. Maintenance involves functional checks, servicing, replacing consumables, cleaning, and other activities. For example, a product that due to its shape or material is difficult or expensive to clean tends to be discarded and replaced easily by the user.

4.4 Upgradability

The needs of the users tend to evolve over time, and these new needs can be attained by the replacement of the product by new versions of updated products, or by the upgrade of the current products. In the circular economy, to develop sustainable solutions, the product must be in use for the longest possible period of time. This can be attained by solutions to upgrade the existing products by developing solutions that promote the technical or aesthetical upgrade potential, with an added value for the user.

4.5 Wear-resistant design solutions

Durable products must be resistant to wear and the loss of properties over time. The design team must consider these aspects and include solutions to minimize them. This can be achieved by the selection of adequate materials, as well as by the design of the product. For example, products that are not user friendly, with complex features tend to have a higher pressure on the structure of the product, leading in most cases to a reduced use due to wear.

4.6 Product-user relation

The challenge for designers is to create products with a stronger emphatic relation with the user. Products that, due to their characteristics, will be attractive for users to purchase, use and maintain (Rocha et all 2015). Designing for attachment and trust or for emotional durability refers to the creation of products that will be used, liked or trusted longer (Bocken 2016).

By attaching this emotional aspect to products, the design team is able to develop solutions that by exploring the potential, will avoid the replacement by other products, reducing the needs of producing and placing more products in the market and therefore, the reduction of impacts in the system.

4.7 Simplicity principle

The simplicity principle has the potential to increase the durability of the products and it can be implemented in several ways. Simple solutions will promote a better use of the product, with a lower margin of error. The simple architecture of the product will promote the reparability and maintenance of the product. Simple and timeless design solutions will avoid disposal due to fashion issues.

	HOW CAN YOU CREATE AND DEVELOP A MORE DURABLE PRODUCT? (1)			
	QUALITY OF MATERIALS	REPARABILITY	MAINTENANCE	UPGRADABILITY
	Identify ideas for a selection of more suitable materials to fulfill the needs of the product and their function	Identify ideas that promote the reparability of your products	Identify ideas that promote the reparability or maintenance of your products	Identify ideas that promote the technical and aesthetical upgrade of you products
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	HOW CAN YOU CREATE AND DEVELOP A MORE DURABLE PRODUCT? (2)		
	WEAR-RESISTANT DESIGN SOLUTIONS	PRODUCT/USER RELATION	SIMPLICITY PRINCIPLE
	Identify ideas to improve the resistance to wear and loss of properties of your product	Identify ideas to create products with a stronger emphatic relation with the user	Identify ideas in order to simplify your product and promote efficient usage
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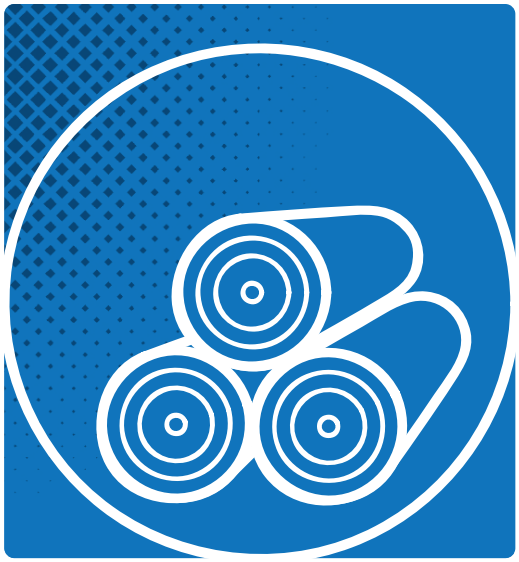
5. Design with Sustainable Materials and Energy



Material selection is a key step in design for circular economy and sustainability. The objective is to select sustainable materials without increasing costs or degrading the product functionality (IEC 62430:2019), seeking the best match between design requirements for the product and material properties (Rocha et al., 2019).

The selection of the energy that is used for and by the product is a crucial factor to be considered as well. In the design phase, the design teams can select materials and energy with lower impacts. The decisions taken in the design phase are fundamental to influence the efficiency and optimization of material and energy consumption in the life cycle of the product or service (Rocha et al., 2020).

The properties and functionality of materials are continuously evolving as a result of material innovation and new and more effective material applications. The selection of materials must have consider their sustainability and the designers should take into account the social, economic and environmental aspects throughout the material's life cycle (BS 8001).

Indicate the current situation. Explain how sustainable are the materials used in the reference product of reference situation	
Indicate the objectives/gaps for your project according to sustainable materials and energy	

What to consider in the design phase

5.1 Recyclable materials

In a circular economy approach, to attain the goal of closing material loops, the selection of materials has an important role. The materials selected for a new product must allow that after its use they can be recycled.

5.2 Recycled materials

In order to maintain the materials in the circular loop, the design solutions must replace virgin materials and consider the selection of recycled materials as much as possible.

5.3 Low embodied energy materials

In the transition to circular and sustainable solutions, the embodied energy should be considered by designers in the development of a product. Embodied energy comprises the energy consumed during the extraction and processing of raw materials, transportation of the raw materials, manufacturing of materials and components and the energy used for various processes during the end of life (Rocha et al 2020). The higher the energy consumption, the higher the environmental impact of the product.

5.4 Renewable materials

The selection of materials to meet the needs of the product must consider the use of renewable materials. These are potentially more sustainable since they are *"resources that are able to be renewed or replenished by ecological cycles or agricultural processes at a rate equal to or greater than consumption so that the products and services provided by these resources are not endangered and remain available for future use"* (BS8001).

5.5 Renewable energy

The design team should evaluate the consumption of energy along the product's life cycle and prioritize the selection of renewable energy sources.

5.6 Non-toxic materials

The selection of materials must consider their toxicity. Hazardous substances in the product must be avoided.

5.7 Efficient materials

Sometimes materials may seem not interesting from a sustainability point of view if

considered alone, however they can have a positive influence on the product system and the life cycle. For example, a material can have a high consumption of energy in its production, but its application on a product will highly increase the durability.

5.8 Fair materials

Fair materials are materials that are fair from a social point of view. The materials used in a product have a direct impact on the environment and on the people that are linked to those materials in all stages of the life cycle. From the conditions in which they are extracted or produced, transported, the consequences of their use in production, use and in the valorization after the use. Problems like pollution, dangerous working conditions, child labour, etc, are linked to the materials "DNA" and these aspects must be considered in the selection of materials.

5.9 Local materials

In the selection of materials, their origin must be a criterion to consider due to the environmental impacts of transport, associated to the consumption of fossil fuels and the emissions. In most of the cases, the preference should be given to materials that are extracted and processed near the production facilities. (Rocha et al., 2015) This aspect also has social impacts that must be considered. Local materials tend to have benefits on local communities.

	WHICH SUSTAINABLE MATERIASL AND ENERGY CAN YOU ADOPT FOR YOUR SOLUTION?			
	RECYCLABLE MATERIALS	RECYCLED MATERIALS	LOW EMBODIED ENERGY MATERIALS	RENEWABLE MATERIALS
	Which recyclable material can be applied in the project?	Which recycled material can be applied in the project?	Considering the embodied energy of materials, which are suitable for the project?	Which renewable materials can be applied in the project?
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	WHICH SUSTAINABLE MATERIASL AND ENERGY CAN YOU ADOPT FOR YOUR SOLUTION?			
	RENEWABLE ENERGY	NON TOXIC MATERIALS	EFFICIENT MATERIALS	FAIR MATERIALS
	How can renewable energy be used by the product?	How can we avoid the use of toxic materials in the life cycle of the product?	Which materials are efficient and have a positive impact in the product system?	Which fair materials from a social point of view can be used ?
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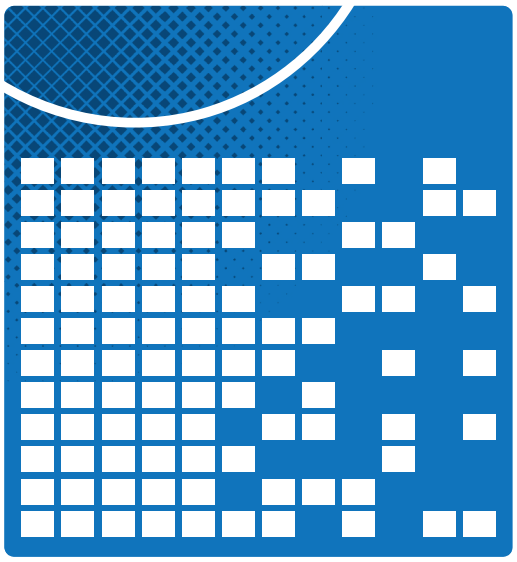
6. Design for Dematerializing the System



"We need to embrace dematerialisation, rethink concepts of ownership and move from resource efficiency to resource sufficiency". Janez Potočnik (Circle Economy, 2021).

We need to change the way to fulfil the needs of the users in a more sustainable and dematerialized way. If we achieve a reduction in the inputs of the material to fulfil the functions, we can achieve a higher circularity level and create more value.

With a dematerialization focus, the designer must deliver a function with no or reduced input of materials, often through moving from physical products to digital alternatives (BS 8001), to services or a combination of both. These new approaches to product and service development can be attained by strategies like the reuse of products and components, sharing, leasing, repair, refurbishment and recycling of products (EEA 2016), among other solutions.

The need towards the dematerialisation of production and consumption are not likely to happen through efficiency improvements. There is a need for shift from the current technological paradigm (Idil Gaziulusoy, 2015) through the design and development of new solutions.

Product/service-systems, as a means to dematerialize the system started to gain momentum due to the high potential for enhanced environmental performance and improved competitiveness (Mcaloone & Pigosso, 2017) and the combination of tangible products with intangible value-added services that lead to dematerialization by reducing the production of waste in the life cycle, by reducing the consumption of resources, and by decoupling the economic growth from environmental impacts, and by creating new revenue streams and extending the residual value of products (Romero & Rossi, 2017).

Indicate the current situation. Explain how the reference product of reference situation is performing according to dematerailization	
Indicate the objectives/gaps for your project according dematerialization	

What to consider in the design phase

6.1 Sharing

Sharing of product in order to meet the needs of the users enables an increased utilization rate of products and services by making possible a shared use or ownership among consumers. It enables customers to access a product, rather than owning it, and use it only as needed (BS8001). With this solution, the same product can satisfy the needs of more users which leads to solutions that use fewer raw materials and can still meet the demands of consumers, or even more.

6.2 Leasing

In leasing solutions, the needs of the users, through a contract with a regular fee, can be satisfied by products or services that are leased from a service provider. The provider retains ownership and is often responsible for maintenance, repair, and control (Rocha et al,, 2020, BS8001).

6.3 Virtualization

Deliver utility virtually. Replacing physical infrastructure and assets with digital/virtual services offers dematerialization advantages over tangible products, but without reducing the perceived value to the customer (BS8001).
Through digitalisation, everything becomes connected, such as intelligent infrastructure, energy networks, the "Internet of things", and social networks (Dutch Ministry of Infrastructure and the Environment & Ministry of Economic Affairs, 2016).

6.4 Increase service component

For the adoption of dematerialized solutions, the design team must develop the system in order to maintain the added value for the users. These solutions, in general, must optimize and increase the services that are provided to the user

	HOW CAN YOU DEMATERIALIZE THE SYSTEM IN WHICH YOUR PRODUCT OPERATES?			
	SHARING	LEASING	VIRTUALIZATION	SERVICITYZE, INCREASE SERVICE COMPONENT
	Identify ideas to meet the needs of the users with a solution in which the product is shared by several users	Identify ideas to satisfy the needs with products or services that are leased from a service provider	How can we deliver utility virtually? How to replace physical infrastructure and assets with digital/virtual services .	Identify ideas to increase the service component of the product or services system
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7. Design for Efficient and Sustainable Production

The Circularity approach is essential in the transformation of industry towards climate-neutrality and long-term competitiveness (European Commission, 2020) and continually challenges current business practices and methods (BS8001). The design practice can support and streamline the production processes to implement circularity, reduction of waste and optimization of resource consumptions, promotion of useful applications for materials, etc (Simeone et al, (2019). Leading the transition, 2017).

Design for an efficient production focuses on adopting design measures and innovative modes of operations that improve the production stage by reducing the consumption of resources per unit of output preventing/minimizing the generation of waste and emissions and improving the efficiency of the outputs, (products and subproducts) (Rocha et al., 2015, BS 8001).

The new product and service solutions should seek to maximise the resource efficiency, thereby minimising the waste production and the recirculation and reuse of waste and secondary products into the production (ESA, 2013) and considering the working conditions under which the products are made, including worker's rights and working conditions (Young et al 2008).

Indicate the current situation. Explain how the reference product of reference situation is produced	
Indicate the objectives/gaps for your project regarding the prodution process	

What to consider in the design phase

7.1 Reduce consumption of materials and energy

In a circular design approach, considering the entire life cycle of the product in the design phase, the design team must consider the production process and its stakeholders and implement measures to reduce the consumption of materials and energy. Simple solutions like changing the shape of a product can have a high impact on the production process by reducing the material needs or by eliminating steps in the productions, or even by avoiding failures.

7.2 Modularity

The adoption of modular solutions can optimize several aspects of the product life cycle. In production, this solution can have benefits at several levels. In production, it can optimize the process, reduce stocks, optimize costs, etc

7.3 Best available technics

Companies that apply the best available technics (BAT), potentially have benefits in terms of production. Usually, the new technics are more efficient in the production and consumption of resources. BAT allow also the integration of new features and developments with a higher potential to innovate.

7.4 Standardization

The use of standard solutions, materials and components in the production process tends to optimize the process, reducing production time, the needs of specific tools and equipment and the consequent reduction of costs. This approach has also benefits in other stages, it facilitates the assembly and disassembly process for repairing, upgrade, repurpose, recycling, etc.

	HOW CAN YOU PROMOTE A BETTER PRODUCTION SYTEM THROUGH DESIGN?			
	REDUCE CONSUMPTION OF MATERIALS AND ENERGY	MODULARITY	BEST AVAILABLE TECHNICS	STANDARDIZATION
	Indicate ideas to reduce the consumption of materials and energy	How can the solution adopt a modular solution?	Which are the best available technics that can be used?	Which standartization solutions can be applied?
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8. Design for Optimal Use

When considering the entire life cycle, the use phase is likely to have the greatest environmental impact. It involves the consumption of resources such as energy, consumables, and outputs such as waste and emissions during the use of the product (IEC 62430:2019).

In the design phase decisions that are made on products are crucial to influence the use phase positively (Rocha et al., 2019). The development team must consider and adopt strategies to prolong the life of the products, components and materials through durability, repair, upgrade etc, (BS8001).

Another crucial aspect is the interface and the relation between the product and the user. Products and services must be user friendly, effective and efficient in supporting the needs of the users without creating additional needs. Designing for an optimal use, will reduce the impacts and added values to the product or service system.

Indicate the current situation. Explain how the reference product of reference situation is performing in the use phase	
Indicate the objectives/gaps for your project for the use phase	

What to consider in the design phase

8.1 Reduce consumables

The design of a product or service must consider the consumables that will be needed for the product fulfill its function. Their optimization in terms of consumption, costs and impacts must be considered. In this stage it is also fundamental to avoid the creation of additional needs for the user.

8.2 Simplicity principle

The simplicity principle is a good approach to attain circular and sustainable solutions. By adopting simple solutions, the product is more user friendly, the product is used better, for longer, risk and damages are minimized and costs are reduced, etc

Through simplicity, by the opposition and in consequence of complexity, designers can potentially grant access to a better quality of life and improved access to technological artefacts and products by allowing its interaction and use in a simpler way (Duarte, 2013), Morseletto, 2020).

8.3 Inclusive design/design for all

Inclusive design, as defined by the British Standards Institute is 'The design of mainstream products and/or services that are accessible to, and usable by, as many people as reasonably possible … without the need for special adaptation or specialised design.' (BS 7000-6:2005).

When designing for the circular economy, the design team should, besides the circularity goals, assure that the solutions attained are sustainable considering the three pillars of sustainability, (environment, economy and society). Therefore, social aspects, which are often forgotten by most teams, are important to sustain the solutions and the welfare of society.

Since the design options have the potential to include or exclude users, it is relevant to consider an inclusive design approach, which emphasizes the contribution that understanding user diversity makes to informing designers decisions, and thus to including as many people as possible as potential users (Inclusive design toolkit).

	HOW CAN YOU OPTIMIZE THE USE OF YOUR PRODUCT?		
	REDUCE CONSUMABLES	SIMPLICITY PRINCIPLE	INCLUSIVE DESIGN/DESIGN FOR ALL
	How can the consumption of consumables be reduced in the use phase of the product or service?	Indicate ideas to simplfy the use of the product or service	Indicate solutions that are inclusive and can be used by all
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9. Design for Recirculation and Zero Waste

The circular economy is seen as a new way to design, produce and use products and services in a more efficient and sustainable way. Based on the principles of elimination of the generation of waste in the system, the recirculation of products and materials and the regeneration of natural systems, (EMF) the adoption of the concept maintains or even increases the value of products, materials and resources in the economy for as long as possible, contributing for an efficient and competitive economy (EC 2015).

The waste, seen as the result of system inefficiency and symbolising bad design options, should be considered as input material, as resources with value and potential to be used in the production process. The shift from "waste" to "resources" can boost the market for secondary materials, products and components. By reusing resources in the system and decreasing the dependence on virgin raw materials, it encourages the redesign of the resource life cycles (Eduzwace, 2020) and the improvement of the entire production and consumption system.

Indicate the current situation. Explain how the reference product of reference situation is performing according recirculation and zero waste	
Indicate the objectives/gaps for your project towards recirculation and zero waste	

What to consider in the design phase

9.1 Design for Reuse

Reuse is an action where products, components or materials can be used again for the same purpose for which they were conceived without the need for any modifications, reprocessing or treatment (BS 8001).
The reuse of products, components or materials means an extension of the utilization period, resulting in a slowdown of the flow of materials from production to recycling (Bocken et al, 2016). In order to promote an effective reuse, the products and services should be designed with features that optimize this potential (BS 8001).

9.2 Design for Recycling

Design for recycling is a method that incorporates recycling and recyclability criteria into the design phase of product intending to obtain recycled or recyclable products. Design for recycling is an important element in a circular economy with the potential to be exploited in order to increase recycling rates and close loops. Recycling is an important step in reducing demand for primary raw materials, minimizes the negative environmental impacts related to the production of primary material as well as reducing the volume of waste by closing the loop of material flows.
In the design phase, aiming to optimize the recyclability of products, the design team should consider the integration of features and properties to optimize the recycling process and optimize the quality of the materials resulting from the recycling process. Criteria such as the selection of materials, the compatibility of materials, the easy dissasembly and separation of different materials, etc, should be integrated in the design of the new product (Schuman, 2019)

9.3 Design for Remanufacturing

Remanufacturing is a production process in which the products, after their use, return to the factory, usually through a take-back system, and the whole product or components that are still in good condition can be used again as inputs for the production of new products. This concept avoids the need to produce new components and reduces the consumption of materials and energy, therefore, reducing the overall impacts of the product in their life cycle.
A remanufactured product should have the quality of a brand new one even when retrieving/reclaiming components from other products used as spare parts (Morseletto, 2020).

In order o allow this solution, the design team should develop the product and its components with this criterion in mind, the quality of the materials and components must allow the remanufacturing process and most important, an efficient take-back system must be implemented.

9.4 Refurbish

Refurbish refers to an aesthetic improvement of a product, component or material, which might involve making it look like new (BS 8001). After the end of their useful life, products can be refurbished in order to extend their lifetime. These solutions aim at restoring an old product and bringing it up to date. In the refurbishing process the function of a product that can be upgraded or modernized. In most cases, it does not involve a full disassembly but the replacement of parts. These products are upgraded and brought back to specified quality standards or satisfactory working and aesthetical conditions (Morseletto 2020).

9.5 Repair

By repairing the products, their lifetime is increased and the needs for the consumption of materials and energy to produce new products is reduced.
Repairing has the potential to retain finished goods and their parts in the economy for longer while maintaining or improving their value. Repair is also making a broken product operational again through fixing/replacing failed parts so it can be used with its original function (Morseletto, 2020).
Through design, features and services to promote the repairing process can be implemented. This consists of developing the product with solutions that allow the repairing process (easy disassembly, using of standard connecting elements, modular solutions, etc), and complemented by the availability of repairing services, availability of spare parts, supporting information on repairing, etc.

9.6 Eliminate waste

The circular economy approach advocates for the elimination of waste in the entire life cycle of the product and service. A zero-waste approach should be implemented by the design teams. In this regard, the team must, according to the specificities of the product or service, identify innovative solutions without the generation of unwanted outputs.
The Zero Waste concept focused on waste prevention that encourages the redesign of the resource life cycles so that all products and components are reused and integrated into the loops aims is for no trash to be sent to landfills, incinerators, the ocean (EDuzwace, 2020) or other.

	HOW CAN YOU RECIRCULATE MATERIALS AND COMPONENTES?		
	DESIGN FOR REUSE	DESIGN FOR RECYCLING	DESIGN FOR REMANUFACTURING
	Which features can you add in the solution to promote the reuse of components or materials	Indicate features to optimize the recycling process and optimization of the quality of the materials resulting from the recycling	Indicate ideas to implement a remanufaturing system
01			
02			
03			
04			
05			

	HOW CAN YOU RECIRCULATE MATERIALS AND COMPONENTES?		
	REFURBISH	DESIGN FOR REPAIR	ELIMINATE WASTE
	Indicate ideas to promote refurbishing in your solution	Which features and services can be implemented to promote the repairing process?	Indicate ideas to eliminate the production of waste considering the entire life cycle of the product or service
01			
02			
03			
04			
05			

10. Design Circular Business Models

In design for a circular economy, as seen in the previous pages, several solutions can be implemented to improve the circular and sustainable profile of products and services.
Many of these ideas can improve the product and the service, however, in most cases, to attain a higher potential for circularity, the business model needs to be adjusted, or new business models need to be created and developed. This new approach to circularity is leading to new businesses, new professions and new ways to fulfil the needs of the users with new opportunities to create greater value for all stakeholders.

Sustainable business models create a competitive advantage through superior customer value and contribute to the sustainable development of the company and society (Lüdeke-Freund, 2010), focused on efficiently offering a system of circular products and value-added services, and supporting circular systems (Romero & Rossi, 2017).

The creation of new sustainable business models promotes the integration of suitable approaches such as reuse, sharing, leasing, repair, refurbishment, recycling etc. By integrating the most suitable of these approaches to one's business- and product development will play a significant role in maintaining the utility of products, components and in realizing circular business models (Mcaloone & Pigosso, 2017).

Indicate the objectives/gaps for your project related to the business model	

What to consider in the design phase

10.1 Innovate the business model

Business model innovation, reflects the adjustments and changes in how a company delivers value to its customers, whether that's through the development of new structures, new revenue streams or new distribution channels. This innovation is focused on a conscious change of the existing business model or the creation of a new business model that satisfies the needs of the customer better than the current existing business models (Godinho, 2019).

10.2 Rethink and create new business models

Rethink the Business Model: Consider opportunities to create greater value and align incentives through business models that build on the interaction between products and services (Circle Economy, 2021). This can lead to the development and creation of new business models with a higher potential of circularity and sustainability

	WHAT IS THE BUSSINESS MODEL OF THE REFERENCE PRODUCT OR SERVICE?	
CURRENT BUSINESS MODEL	Describe the current bussiness model	
FOR REFLECTION	HOW CAN WE INNOVATE THE BUSINESS MODEL?	
DEVELOP NEW BUSINESS MODELS	Identify new business models that can be aplied for your solution	

NEW CONCEPT
development

NEW PRODUCT OR SERVICE AND BUSINESS MODEL FOR THE PROJECT/SOLUTION?
Based on the options selected develop the new product or service and describe the business model

NEW CONCEPT development

	DESCRIBE YOUR PRODUCT ACCORDING TO THE LIFE CYCLE STAGES
RESOURCES	Identify and describe the resources used in your product, considering materials, energy and water
PRODUCTION	Describe how your product is produced
DISTRIBUCTION	Describe how the product is distributed
USE	Describe how the product is used, including the use, consumables, maintenance, repair, etc
END OF FUNCTIONAL LIFE	Describe what happens after the functional use of the product

NEW CONCEPT - impacts

	IDENTIFY THE MAIN IMPACTS RELATED TO THE STAGE	
RESOURCES	Identify the impacts related to the resources used in your product	
PRODUCTION	Identify the main impacts related to the production	
DISTRIBUCTION	Identify the main impacts related to the distribution	
USE	Identify the main impacts related to the use of the product	
END OF FUNCTIONAL LIFE	Identify the main impacts related to the end of funcional life of the product	
Explain how the impacts were identified	In this field describe the source of the inputs. Are they based on a Life cycle analisys? Qualitative or quantitative?	

#4 Circularity assessment

For an assessment of circularity performance of the design process and the solutions developed

Circularity performance

Qualitative assessment of the circular approach in project design

How to asses the project and the results attained?

The **Design process Circularity Assessment** tool aims to evaluate the performance of the design project and its results, and how it contributes to the transition to circularity. Within the Rounding the vertices concept, with the tool, the user can assess how much the process led to a circular approach and how much the vertices of the initial square shape which represents the reference product was improved towards a more circular process and results.

The assessment relates the performance of the 10 design for circularity principles, which covers the entire design process, and reflects their impact in the four levels for circularity; the function level, the resources level, the social level and the economic level.

The tool results in a set of information, presented through chats, in which the user can:

- identify the overall performance of the project, meaning how much the vertices were rounded,
- the performance of each principle, and to what extent the principle was adopted in the process
- the performance of the project according to the four levels for circularity
- the impact of the performance of the 10 principles in the transition to circularity

These results are useful to demonstrate and communicate the results of the design for circularity and sustainability project, indicating where the improvements were performed and pointing out the potential for further improvement through a new design process.

Structure

The tool is composed of an introductory spreadsheet, 10 spreadsheets to evaluate the 10 design for circularity principles and a final spreadsheet with the results of the assessment. In the evaluation spreadsheets, the user should rate the level of integration of the principle in the project on a scale from 01 to 05 and explain how it was implemented.

In each spreadsheet, there is also and a brief explanation of why the principle is important in the design process.

In the final spreadsheet, the results of the assessment are displayed in a set of charts and a final table with the evaluation of the principles and their impact on the four levels. Since each principle has a different impact on each circularity level, their importance was weighted based on literature and in consultation with experts.

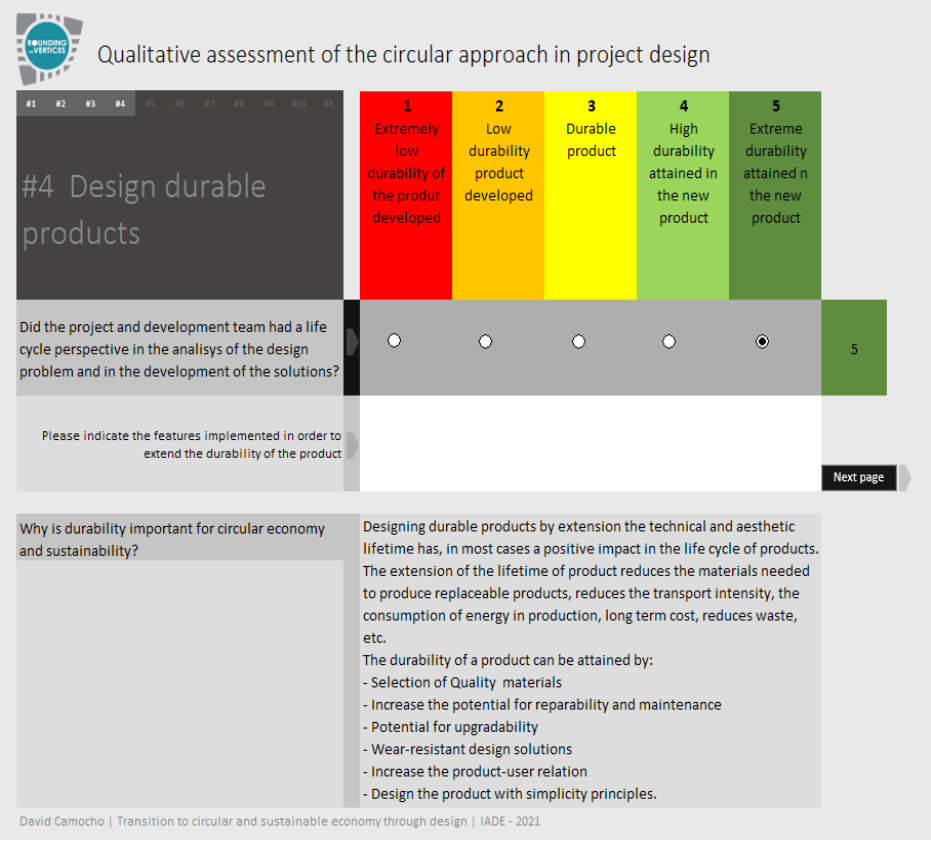
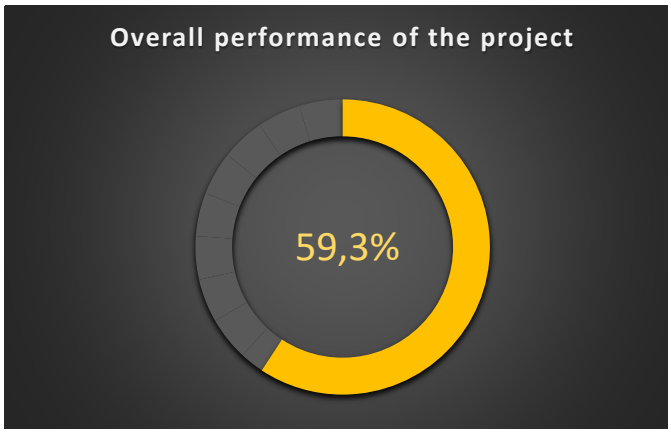
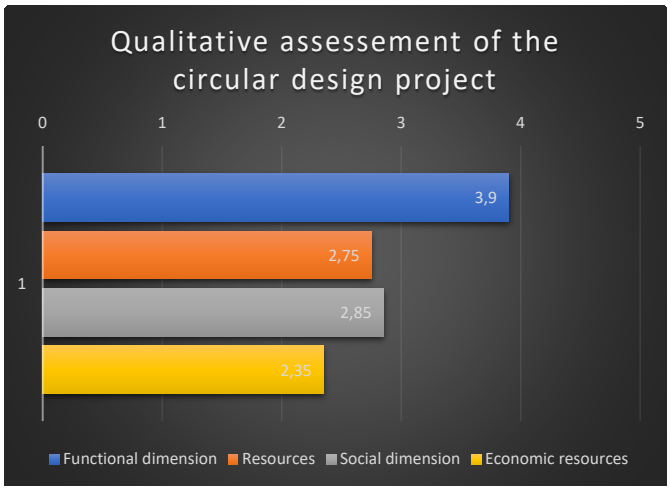
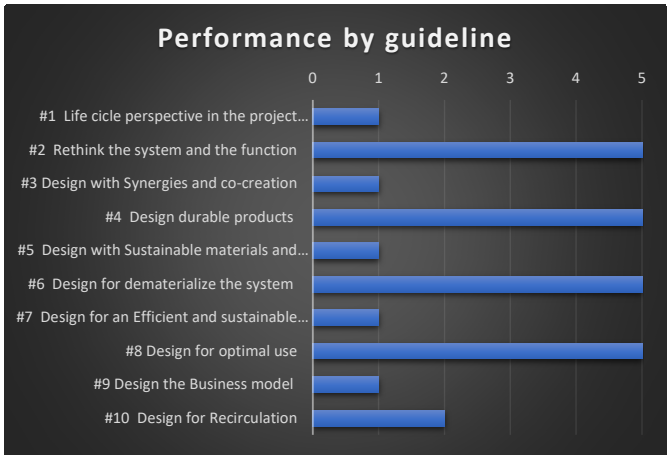


Figure 6: Assessment spreadsheet Design durable products

Results



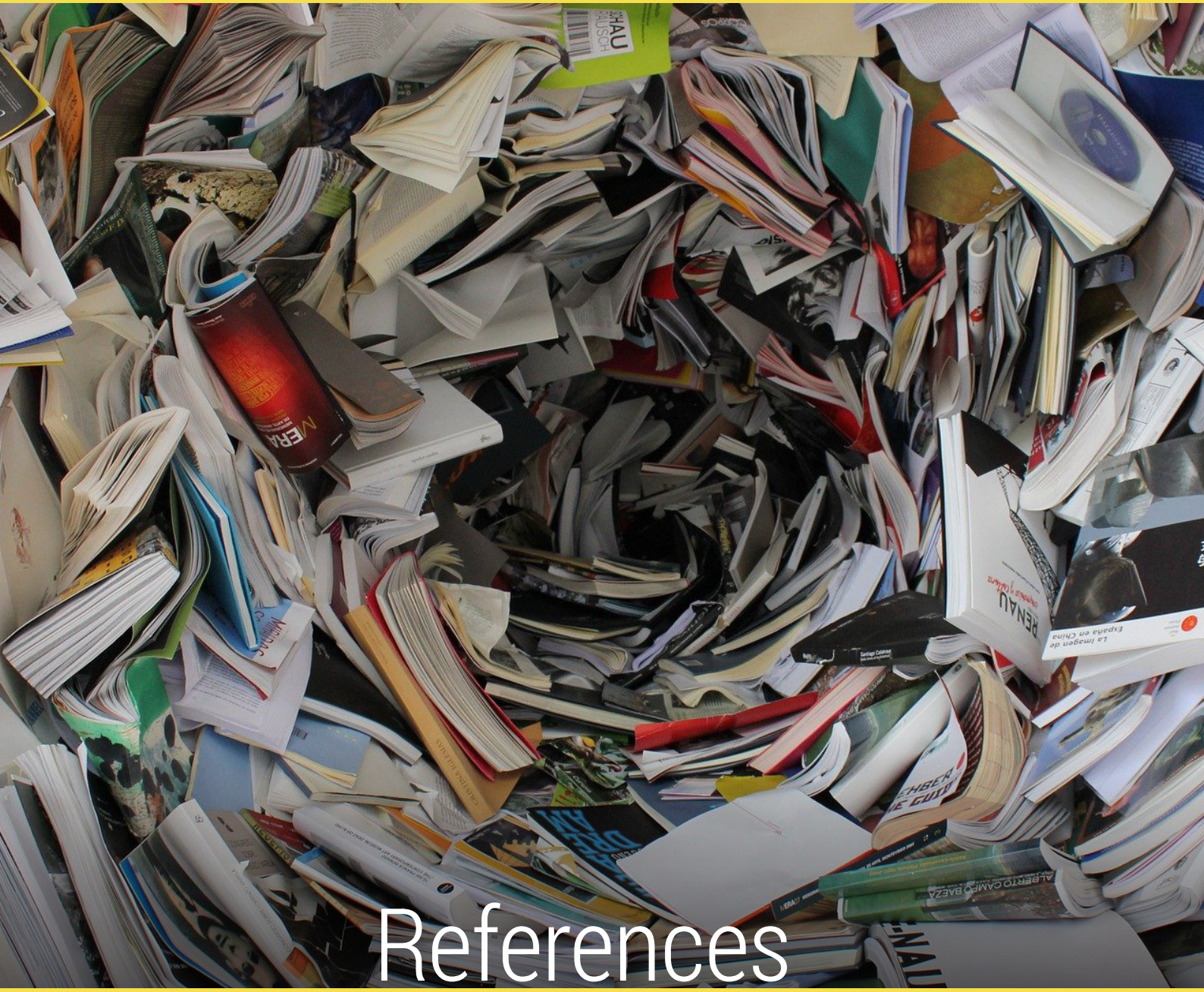




Through the inputs and the assessment of the performance in the implementation of the 10 circular design principles, the tool calculates:

- **The overall performance of the project**, indicating in which percentage the project fulfils the aim of rounding the vertices. In order to reach the maximum score, the project has to implement all the principles scoring 5 on the assessment scale from 01 to 05.
- **The performance of the four levels**, how the project and the results are performing in terms of the function of the product, the resources used within the life cycle, the social aspect and the economic aspects of the product or service. To reach the full potential in the transition for circularity, the project must address these four aspects and improve them in all stages of the life cycle.
- **The performance of each principle**. This detailed scoring allows a brief demonstration of where the product is performing better and where there is the need to improve the process towards circularity.

Figures 7-9 : Results of the assement tool / example



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