Product-Service Development for Circular Economy and Sustainability Course

Training Modules

Introduction to the circular economy	Business models	Value chains
Processes and materials	KATCH-e	**Design and development**
Radical innovation and collaborative design processes	Life cycle perspective	Communication

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Module Design and development

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More information about the project, training materials and contacts, available at:

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Design and development

Contents

Learning objectives

- Understand the role of design and designers in the circular economy model
- Get acquainted with circular design concepts and strategies
- Be able to select and apply circularity strategies in the design and development process of products and services, in a holistic manner
- Get acquainted with circular design tools and be able to apply them in product and service design and development
- Be able to transfer the knowledge and skills onto own project and to implement it

Previous knowledge

- Basic understanding of circular economy (Module Introduction)
- Understanding of LC perspective (Module Life cycle perspective)

What, who, where, when, why and how

What	Presentation of design for circular economy strategies and a step-by-step development process, as well as examples.
Who	All designers and professionals who develop products and product-service systems with circularity and sustainability criteria.
Where	In any University, centre, company or institution that works in the topics of the KATCH_e project, with an emphasis on construction products and furniture.
When	At the very beginning of the design process.
Why	Design and development teams need to be familiar with design for circular economy strategies, criteria and methods to be able to integrate such considerations in the creation of new products and Product-service systems (PSS).
How	Having a good understanding of the strategies and how to apply them in the design and development process, in a holistic manner.

Questions the module addresses

This module is built around the following question: how can the design of products and services contribute to the circular economy (CE). The module answers the question both from a conceptual perspective and from a practical implementation perspective. The contents are structured in 7 chapters with proposed assignments in each of them. To work on the assignments, one can use the provided background materials or do your own empirical research. The following table provides an overview of questions which are addressed within the contents as well as the assignments of the module.

Chapter 1: From ecodesign to design for the circular economy and sustainability	
Contents	– What are the main differences and commonalities between ecodesign, design for the circular economy and design for sustainability? – Closing, slowing and narrowing resource loops: what does this mean in the field of design?
Assignments	– Think of a specific product, e.g. a wooden floor. Discuss what does each type of approach (slow loops, close loops, narrow loops) mean for this product: how do these approaches change the product? And what are the environmental, social and economic implications? – Identify products you know that illustrate design approaches to slow, close and narrow resource loops. – Identify services you know that illustrate design approaches to slow, close and narrow resource loops.
Chapter 2: The role of design in circular economy	
Contents	– How can design contribute to a circular economy?
Assignments	– Group discussion: what are the main differences between the design profession in a traditional, linear economic model and a circular economy model? Think of designers as having a broad role in the company, not only product designers but also service and business model designers.

Chapter 3: KATCH_e strategies of design for a CE	
Contents	– Which are the product and service design strategies that lead to circular economy and sustainability? – How can they be organized and how do they relate to closing, slowing and narrowing resource loops? – What are the main characteristics of each strategy?
Assignments	– Select two strategies and search for examples of products or services that correspond to those strategies. Describe the examples using the same criteria as in the chapter and discuss the overlapping and complementarity between strategies. – Read the following product features and identify the CE design strategy(ies) that best fit with them: 1. A textile upholstery for sofas made with 100% recyclable textile. 2. A durable kitchen worktop material. 3. An easy to repair kitchen worktop material. 4. Leasable furniture. 5. An armchair frame made with wasted wood generated in the manufacturing of ships. 6. Furniture for kids that grows with the child. 7. A modular windows frame design that is capable to adapt to future changes: bigger windows or need to partial replacement of the window frame. 8. Wall shelves made with disposed doors. 9. A modular sofa able to be enlarged and assembled in different ways to adapt to new spaces or layout changes.

Chapter 4: Product and service design step-by-step	
Contents	– How can a product or service design service be organized in 8 steps? – Which activities are carried out in each step?
Assignments	– Think of a furniture product to be redesigned in a circular design project. – Consider the eight steps of the project: 1. Planning of the project 2. Needs analysis – research 3. Definition of the circular design strategy 4. Product and service development 5. Prototyping and testing 6. Evaluation of the new product or PSS and of the project 7. Production 8. Follow-up activities – Identify at least two tasks in each step to align your project with circularity and sustainability.

Chapter 5: Design for CE in the construction sector	
Contents	– How do construction products relate to the buildings they are integrated into, when circularity is an ambition? – Which are the most important design challenges?
Assignments	– Observe the room you are in (classroom, office room, at home, etc.). – Define a different use for the room in 20 years' time (for instance, the room will be a dance room because the building's purpose will change into a performing arts centre). – Identify one element of the space plan and stuff layers (according to Brand) that will need to be adapted for the new purpose and discuss design options for these elements according to the eight KATCH_e Design for Circular Economy strategies.

Chapter 6: Tools for product and service design for circular economy	
Contents	– Which tools support design for circular economy?
Assignments	– Exercise with the CE Designer: Using a specific product, service or problem, apply the tool to analyse the circularity profile and identify improvement measures according with the results of the tool. The coffee-machine example can be used as a basis to perform the exercise (the product and data were developed for the exercise and are fictitious). – Exercises with other tools: Use the same product and data and apply it to the other tools presented in chapter 6. Compare and discuss the results attained with the different tools.
Chapter 7: Examples	
Contents	– Where can I get inspiration of design for circular economy strategies applied to products and services in the construction and furniture sectors?

Executive summary

Chapter 1: From ecodesign to design for the circular economy and sustainability

This chapter deals with key concepts to understand the rest of the module. While the relationship between circular economy and sustainability is not well established, the KATCH_e project adopted a broad definition of the former, and thus design for the circular economy is here defined as "a product-service design and development that replaces conventional end-of-life concept by closing, slowing and narrowing the resource flows in production, distribution and consumption processes. It is enabled by innovation and novel business models and aims to accomplish sustainable development through maximising of ecosystem functioning and human well-being, and through responsible production and consumption".

Building upon existing literature in the field, it distinguishes design approaches for slowing, closing and narrowing resource loops and dedicates one section to product-service systems, as the transition from selling products to adding and providing services is at the core of circular economy.

Chapter 2: The role of design in circular economy

This chapter is important for design students and professionals to reflect on their role to promote circular economy. As Michael Braungart and William McDonough (2002) put it, "We don't have a waste problem, we have a design problem".

Chapter 3: KATCH_e strategies of design for a CE

Within the project, eight design for circular economy strategies have been developed and are explained in this chapter. They are in line with the project's understanding that the circularity concept needs to be placed within the overall goal of sustainable development. Therefore, there are social sustainability criteria integrated into the different strategies.

The eight strategies concern product and service development. They are:

1. Design of long-life products
2. Design for product-life extension
3. Design of product-oriented services
4. Design of use- or result-oriented services
5. Design for recycling
6. Design for remanufacturing
7. Design for materials sustainability
8. Design for energy sustainability

This chapter proposes a methodology based on eight general steps that should be adjusted to each particular project. The steps firstly describe the work performed in product design, in this case having in mind circular design. Then, the description of services design follows, highlighting when needed the related specificities.

Chapter 5: Design for CE in the construction sector

This chapter discusses the characteristics of products to be integrated into buildings where circularity is an objective. The challenge of combining long life spans with adaptability in buildings is reflected in construction products' design. The shearing layers of a building defined by Stewart Brand in 1974 deserve new attention in the context of circularity and are included in this chapter to discuss different life spans of construction products.

Chapter 6: Tools for product and service design for CE

This chapter addresses the topic of tools. Within KATCH_e, three tools have been developed that are relevant for this module: (i) the CE Designer checklists, a semi-quantitative tool for prioritization, assessment and idea finding of circular solutions for product and/or service (re)design, following the eight strategies presented in chapter 3; (ii) CE Journey, which helps users to assess the overall product, service and system journey and (iii) KATCH_Up Board Game, that stimulates the players to generate value ideas from a business challenge, applying circular design and circular business strategies. In addition, several other tools that can be found in the literature.

Chapter 7: Examples

Examples, both from the construction and furniture sectors, are provided in this chapter.

1. From ecodesign to design for the circular economy and sustainability

1.1 Ecodesign, design for sustainability and design for the circular economy: complementary concepts

The integration of environmental considerations into product design with the objective of reducing products' environmental impacts along their life cycle (ecodesign, also known as life cycle design (LCD) and design for the environment (DfE)) has been developed and implemented in companies since 1990's (de Pauw et al., 2014; Stevels, 2009). It is at the design stage that most of the characteristics of a product throughout its life cycle (from raw-materials extraction and processing, manufacturing, distribution, use, end of life) are defined. Thus, the role of design in influencing products' environmental impacts has been the subject of great attention in the academic and practitioners communities.

Key characteristics of ecodesign include:

- Life cycle thinking (i.e. considering the environmental aspects – inputs and outputs – and associated impacts, such as climate change, resources depletion, toxicity, air, water, and soil pollution, etc., at each life cycle stage) (Thrane and Eagan, 2005);
- Early integration (i.e., addressing environmental considerations at the earliest possible stage of product development, when there is more room for introducing radical changes to the product concept and optimize outcomes) (Thrane and Eagan, 2005);
- Functional thinking: it is not only a single product to be designed that matters, but the function delivered by the product itself (Vezzoli and Ceschin, 2011).

To deal with the challenges that underlie the sustainable development concept, companies have to change drastically the way they address product and service design and development. The ecodesign concept has evolved to broader design dimensions described as design for sustainability (DfS) (figure 1).

In contrast to the current practice of ecodesign, where in most of the cases only incremental environmental improvements to existing products and services are achieved, DfS aims at radical improvements in the three dimensions of sustainability: not only the environmental and economic ones but also the social dimension.

Some definitions of ecodesign derived to distinguish it from mainstream design, go beyond incremental gains. However, these definitions were made in the absence of DfS as an additional category (Spangenberg et al., 2010). DfS broadens the horizon and challenges established practices. It creates an additional level of complexity and makes solutions less clear-cut and therefore riskier (which is inevitable in leapfrogging solutions when compared to incremental improvements). Figure 1 also highlights that whereas in ecodesign the social dimension of sustainability is not considered, such dimension is inherently part of DfS. Examples of socially oriented design strategies are inclusive design, design products that do not require dangerous tools to promote good working conditions in production, involving communities in design, etc. (Rocha and Schmidt, 2014).

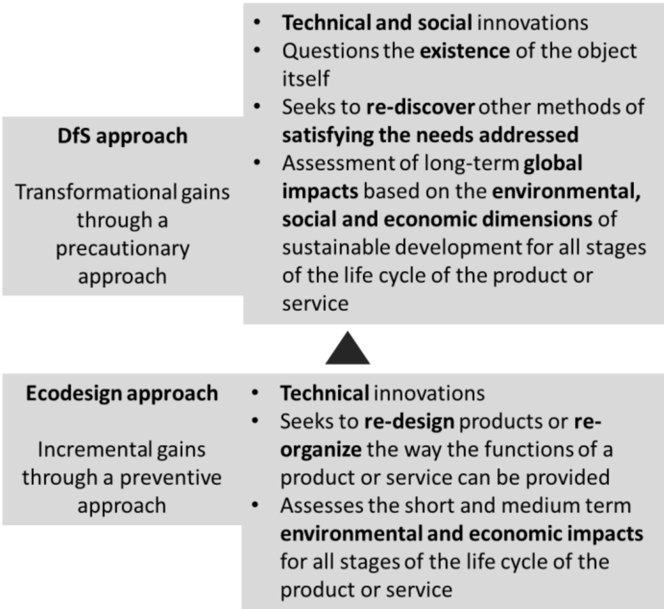


Figure 1 – From ecodesign to DfS (Spangenberg et al., 2010).

The ecodesign and DfS concepts have been developed within a linear or quasi-linear economic model, to which CE offers a practical alternative, fuelled by the widespread adoption of disruptive technologies (such as ICT – Information and communication technologies) that allow massive and fast change (Het Groene Brein, n.d.). Therefore, design for the circular economy (CE) is gaining remarkable attention.

CE is about "maintaining the function and value of products, components, and materials at the highest possible level and extend their lifespan". The right combinations of product and service design strategies support circular economy by (Bocken et al., 2016):

- Closing resource flows: through recycling, the loop between post-use and production is closed, resulting in a circular flow of resources
- Slowing resource flows: the utilization period of products is extended and/or intensified, resulting in a slowdown of the flow of resources
- Narrowing flows: using fewer resources per product or service unit.

Figure 2 illustrates the closing, slowing and narrowing resource flows that is demanded by CE and the implications for product and product-service systems (PSS) design and development will be discussed. It should be noted that for these products and services to be successful in the market, companies need to develop adequate business models (see the *KATCH_e **Business models** module*).

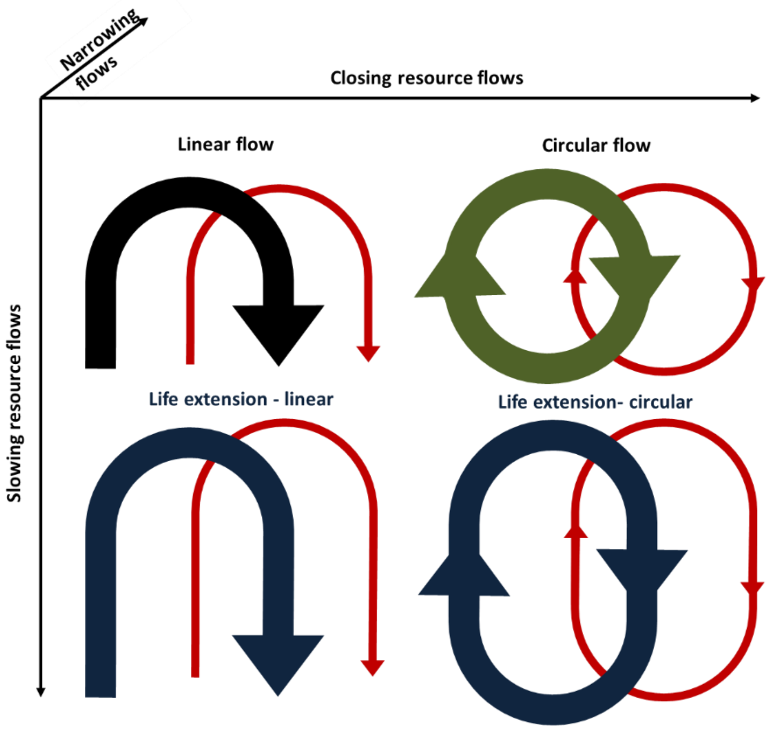


Figure 2 – Categorization of linear and circular approaches for reducing resource use. (Bocken et al., 2016)

The KATCH_e project proposes to adopt an integrative approach to the concept and practice of design for the circular economy. Unlike most publications and experiences in the field, that focus on slowing and closing resource loops (and disregard the dimension of narrowing loops since it applies also to a linear model) and do not consider the social dimension of sustainability, the KATCH_e project adopted the following definition:

> *Design for circular economy is a product-service design and development that replaces conventional end-of-life concept by closing, slowing and narrowing the resource flows in production, distribution and consumption processes. It is enabled by innovation and novel business models and aims to accomplish sustainable development through supporting ecosystem functioning and human well-being, and through responsible production and consumption.*

When it comes to product and service design, what do “slowing loops”, “closing loops” and “narrowing loops” mean? Table 1 presents examples of design approaches to make products more durable, to avoid that they become waste and to increase their use of resources. These approaches and strategies are further developed in chapter 3.

Table 1: Product design approaches for the circular economy

Product design approaches to slow loops = Design for durability
– To design long-life products – To foster a strong product-user relationship – To produce resistant, easy to maintain and repairable products – To use modularity, to allow the upgrading and adaptation of products
Product design approaches to close loops = Design for recycling
– To develop products in such a way that the materials can be continuously and safely recycled into new materials and products – To use safe and healthy materials for those products that are consumed or worn during use, and thus create food for the natural systems – To make it easy to dis- and reassemble products
Product design approaches to narrow loops = Design for resource conservation
– To use a preventive approach in which products and services are designed so that resources use is minimized in the whole life cycle – In addition to quantity, to choose more sustainable materials and energy sources when designing a product or a service

Assignment 1

Think of a specific product, e.g. a wooden floor. Discuss what does each type of approach (slowing loops, closing loops, narrowing loops) mean for this product: how do these approaches change the product? And what are the environmental, social and economic implications?

Assignment 2

Identify products you know that illustrate design approaches to slow, close and narrow resource loops.

Design for the circular economy or circular design takes a new angle when dealing with environmental considerations in design:

- **Inspiration by natural systems**, where materials flow in cycles and there is no waste – everything should be a nutrient in the biosphere and the technosphere; this is a step forward, compared to previous approaches like ecodesign, which assumed that all products inevitably become waste at a certain point in time;
- **Dematerialization**, through the transition from selling products to providing services or product-service system solutions that drastically reduce the intensity of materials per unit of service provided (see the chapter on product-service systems);
- **"More good instead of less bad":** unlike in a traditional eco-design approach, which focuses on eco-efficiency with the goal of minimizing the cradle-to-grave flow of materials, circular design aims at eco-effectiveness, i.e. the transformation of products and their associated material flows so that they form a supportive relationship with ecological systems and future economic growth (Ellen MacArthur Foundation, 2015). The aim is to have a positive impact. As a matter of fact, eco-efficiency is necessary but needs to be coupled with other strategies to counteract potential rebound effects (selling more products, even if each one is more eco-efficient, may result in a greater environmental impact).
- **The Inertia principle:** "Do not repair what is not broken, do not remanufacture something that can be repaired, do not recycle a product that can be remanufactured. Replace or treat only the smallest possible part to maintain the existing economic value of the technical system" (Stahel 2010, 195). The starting point for designers is the original products, it is about product integrity. On the other hand, in ecodesign one of the guiding principles is the waste hierarchy, in which the definitions of prevention (the preferred option), reuse, recovery, recycling, and disposal (the least preferred option) all are based on the assumption that eventually a product becomes waste, and a priority order for managing waste is provided. This focus on waste does not make sense in a CE (den Hollander et al., 2017) because, theoretically, the phase when a product is disposed of does not exist and after its use, all materials should be incorporated in the loop.
- **Systems thinking:** circular design elevates design to a systems-level (van den Berg and Bakker, 2015). This means understanding the complex and interconnected nature of any system of which a product is part, e.g. by identifying all components and material inputs in the life cycle, the ways the natural systems are impacted and the stakeholders involved (including the users), and understanding how decisions regarding such product interact with the wider system (BSI, 2017). Systems thinking can help designers to manage complexity more effectively (BSI, 2017) and avoid the negative consequences of poor planning.

1.2 Product-service systems

The product-service systems (PSS's) concept has been a matter of great attention for sustainability experts due to its potential to decouple revenues from material flows and to increase resource productivity. In other words, whereas in the traditional product-oriented business model, the company revenues depend on the number of units sold (and the pressure to continuously grow in sales leads to unsustainability), in a service-oriented business model the company sells a result or an access and owns the products: the less products they need, or the longer the products last with good quality to provide the service, the better for the company. Product-service systems have a high potential for circularity and sustainability (if developed with circular and sustainability criteria) and are based on business models which deliver added-value products and services that meet the needs of users more sustainably (see the *KATCH_e* ***Business models*** *module*). In these systems, the focus is in the service that the user receives from a product and on the way the customer uses a product's function, rather than on the product itself. This systemic approach has a crucial role in the transition to a more circular economy.

PSS's are an innovative approach to sustainable business and may allow a company to (Crul and Diehl, 2009):

- Identify new markets and ways to profit;
- Survive and adapt to rapidly changing markets;
- Increase efficiency and reduce resource consumption;
- Compete in the market and generate value and social quality, while decreasing total negative environmental and social impact (directly or indirectly).

To implement circular economy in practice, focusing on an efficient transition from the linear model to a circular model, the way users' needs are fulfilled needs to change and innovative systems and business models have to be created. In this context, innovation is considered to be fundamental in guiding businesses towards a transformation of practices influenced by the design and functions (see the *KATCH_e* ***Radical innovation and collaborative design processes*** *module*).

PSS's are not a new concept, but when properly designed they have the potential to change production and consumption patterns towards a circular and sustainable future. Figure 3 offers a possible systemization of PSS's.

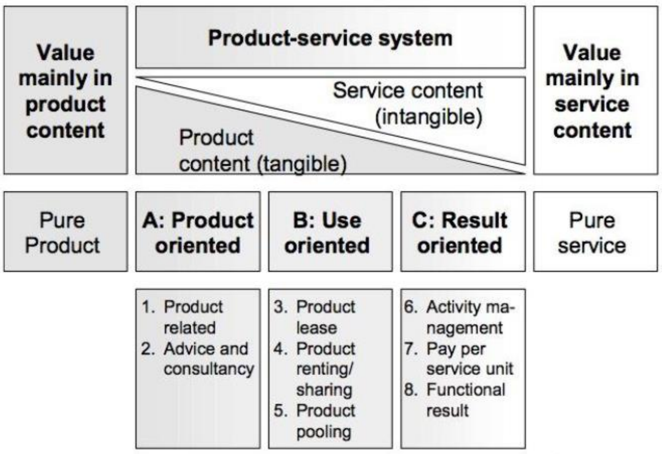


Figure 3 – Eight types of PSS's (Tukker, 2004)

Several categories of PSS's can be identified and the distinctions among the different forms are based on the extent of product ownership, the type of products involved, and the value-added of the service level (Tukker et al., 2006). The expression PSS highlights that there are neither "pure products" nor "pure services", but rather combinations of both. For simplicity, from this point onwards this module refers simply to services instead of PSS's, disregard the weight of the tangible or the intangible component.

- Category A: **Product-oriented services**. Here, the focus is still mainly geared towards sales of products that are owned by the user or consumer, but some extra services are added.
- Category B: **Use-oriented services**. The traditional product still plays a central role, but the business model is not geared towards selling products. Product is owned by the service provider who sells functions instead of products, through modified distribution, payment systems and sometimes the product is shared by several users.
- Category C: **Result-oriented services**. Here, the client and provider agree on a result, and there is no pre-determined product involved.

Table 2: Categories of services with examples

Category A: Product-oriented services – The product is owned by the user/consumer
Product extension service, the value of a product is increased through additional services, e.g. upgrading, repair, guarantees, financing schemes, the supply of consumables, etc. **Advice and consultancy** concerning the most efficient use of the product. **Vertical Integration**, meaning modified delivering strategies to supply products to customers, retailers and/ or customers who get directly involved in the process of production, e.g. production on demand.
Category B: Use oriented services – The product is owned by the service provider who sells functions instead of products, through modified distribution and payment systems
Leasing. The provider retains ownership and is often responsible for maintenance, repair, and control. The leaser pays a regular fee for the use of the product and normally has an individual and unlimited access to the leased product. **Renting or Sharing**, similar to leasing but the user does not have unlimited and individual access to the product. The same product is sequentially used by different users. **Pooling**, which is similar to sharing but there is a simultaneous use of the product.
Category C: Result oriented services – There is not a pre-determined product involved in this category
Activity Management, the supplier gives incentives for the customer to consume more efficiently and optimises a system e.g. by using modified payment systems, e.g. contracting. **Pay-per-service unit**, the user buys the output of the product e.g. pay per lux by Philips, a service in which the user buy light, and nothing else. **Functional result**, products are substituted by new solutions; the delivery is a result which is not related to a specific technology system anymore. Examples are pest control service instead of pesticides, delivery of a "pleasant climate" instead of selling heating or cooling equipment, etc.

Sources: INEDIC project; Tukker, van den Berg, & Tischner, (2006) Tukker, (2003)

As shown in table 2 the ownership and reliance on a physical product decrease from the first type to the last one. On the other side, the freedom of the provider increases. In the last examples, the user does not want a specific product or service, he/she wants a function, something to solve a problem or need, and the provider is free to find any type of solution to solve the problem (Tukker, 2004).

In the context of circular economy, it is again possible to relate the slowing and closing resource loops to the three types of services above presented (table 3).

Table 3: Services for the circular economy (BSI, 2017)

Services to slow loops = product-oriented, use-oriented and result-oriented
– Maintenance, repairing, reuse services that extend the lifetime of products (product-oriented) – Sharing, leasing and renting are services that provide the capability to satisfy user expectations without needing to own physical products (use-oriented, sharing economy, “from consumer to the use”) – In services that deliver performance, the client or consumer is only interested in the result and not at all in the product or technology behind it (result-oriented)
Services to close loops = reverse logistics
– Collection and sourcing of otherwise “wasted” materials or products to turn them into new forms of value such as reuse, remanufacturing or recycling.
Services to narrow loops = digitalization
– Delivery of a function with no or reduced requirement for materials; digitalization is a very strong enabler for reducing material resources use.

Assignment 3

Identify services you know that illustrate design approaches to slow, close and narrow resource loops.

2. The role of design in circular economy

> "We don't have a waste problem, we have a design problem"
>
> Michael Braungart and William McDonough, Founders of the Cradle2Cradle concept

Design plays a crucial role in circular economy and this is not only about recycling, but also about maintenance, repair, sharing, reuse, refurbishment and remanufacturing. Design has the power of enabling or hindering these features. It determines the circularity potential of products, services and systems. Traditionally, designers would focus exclusively on products, but their role is evolving. The power of design lies on its ability to ask fundamental questions, such as: What is the real purpose of this product? Which is the need that this product fulfils? Are there other solutions to respond to such need, e.g. through a service? Is it possible to increase well-being and happiness through this design? Does this design have a negative impact on the environment? A zero one? A positive one, contributing to the regeneration of ecosystems? And in society? (De Groene Zaak and Ethica, 2015).

Traditional manufacturing is wasteful because it focuses exclusively on the end-user. The circular economy mind-set looks much wider, to consider everyone who extracts, builds, uses, and disposes of things. By zooming out from users, to consider the wider network of stakeholders, we can unlock value at every stage of the process. As a designer, that includes building feedback loops into your work; knowing the life cycle of materials you use; collaborating with other industry stakeholders; and considering unintended consequences (Ellen MacArthur Foundation and IDEO, 2017).

Given that the design of a product directly influences the way a value chain will be managed, building circular, globally sustainable value chains inevitably signifies a fundamental change in the practice of design. A variety of new capabilities are key to design for a sustainable future; these range from a deeper knowledge of material composition to a rich understanding of social behaviour (De los Rios and Charnley, 2017).

Many examples illustrate the role of design in a circular economy. In the KATCH_e Knowledge Platform (KATCH_e, n.d.) there is a large collection of them from the construction and furniture sectors. The last chapter of this module also provides various examples where different design strategies (see chapter 3) have been applied.

One interesting case comes from the British company CRISSCROSS Furniture Ltd. (Crisscross, n.d.). They offer modular, flat-pack furniture, whose main novelty relates to the easiness of assembling and disassembling and the possibility of reconfiguring the furniture. The furniture collection, designed by Sam Wrigley, comprises cupboards, wardrobes, a bedside table and desk. They are assembled using modules that are slotted into pre-existing holes in the boards and can be fixed in place without the use of any tools, allowing them to be easily removed and reused.

The relevance of this example, from the point of view of circular design, relates to:

- The use of eco-friendly materials: birch plywood from sustainable FSC© certified forests and natural plant-based wood waxes;
- The durability of the products: they are made of high-quality materials; in order to endure frequent use and disassembly, the brackets, hinges, and locknuts are made from high-grade aluminium that is anodised black. Furthermore, the easiness of disassembly and reassembly with different configurations and without the need of tools gives the possibility of adapting the furniture to different needs and spaces over time;
- The recyclability: the products and packaging are 100% recyclable.

Figure 4 – CRISSCROSS furniture. Source: http://www.crisscrossfurniture.com/

Product design determines the circularity potential of a product because it establishes to a large extent its characteristics and features, which is the functionality, which materials are used in the product, how long it is supposed to last, its reparability and recyclability, etc. However, whether or not this potential is realised depends on how the product is managed throughout its life cycle (European Environment Agency, 2017).

The circularity of a product depends not only on its intrinsic properties but also on the system in which the product is integrated (European Environment Agency, 2017). For instance, the reparability of a product comes into effect if there are repair services and proper business models in place. The role of designers has expanded from product design to service, business models and systems design (Ceschin & Gaziulusoy, 2016). The KATCH_e project addresses these dimensions of the designers' work in different modules, as shown in figure 5. The remaining KATCH_e modules (Introduction to the CE, Processes and materials, Life cycle perspective and Communication) offer foundations that support this work. Although figure 5 concerns "designers for sustainable development", it applies also to "designers for a circular economy".

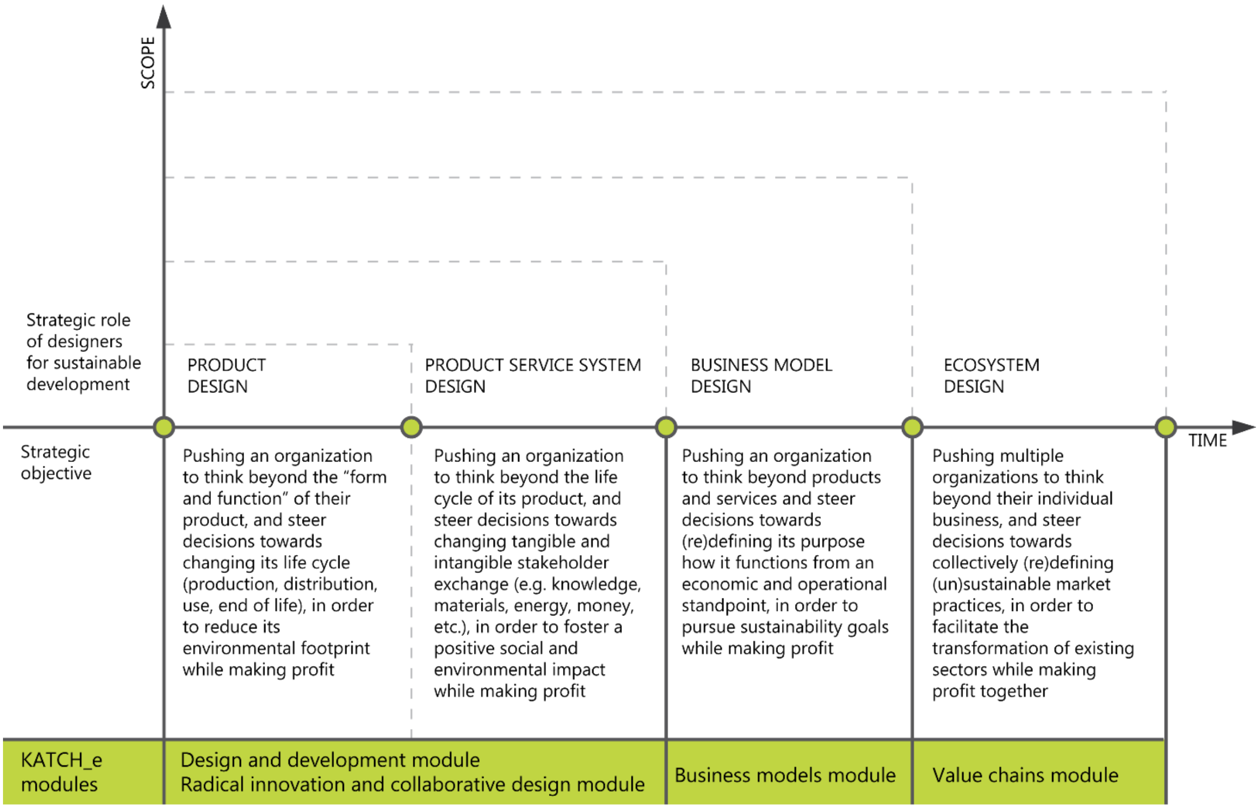


Figure 5 – Evolution of the strategic role of designers for sustainable development (Baldassarre et al., 2019) and KATCH_e modules contributing to the different roles.

Assignment 4

Group discussion: what are the main differences between the design profession in a traditional, linear economic model and a circular economy model? Think of designers as having a broad role in the company, not only product designers but also service and business model designers.

Note: this assignment can be performed separately or be integrated into the last assignment of this module.

3. KATCH_e strategies of design for a CE

3.1 Introduction

The KATCH_e strategies of design for circular economy have been developed using a significant amount of literature and guidelines related to circular design. Nevertheless, given the understanding of design for a CE in the context of the project, special attention has been devoted to include the social dimension of sustainability and strategies related to "narrowing loops", as explained in chapter 1. Chapter 3 provides an explanation of the strategies and the link to the KATCH_e **CE Designer**, which is a dedicated tool also created, tested and validated in the project, which provides practical support to the implementation of circularity in the design process:

The strategies are organized and were established having the following assumptions in mind:

- They are in line with the project's understanding that the circularity concept needs to be placed within the **overall goal of sustainable development**. Therefore, there are social sustainability criteria integrated into the different strategies;
- They are organized according to the **three main types of loops in CE** as they were presented in chapter 1 (see also the *KATCH_e **Introduction** module*): *slowing resource loops*, where the key idea is *durability*, and *closing resource loops*, where the key idea is *recycling*; they correspond to the design strategies in the left and right column of table 4; such strategies ought to be combined with those related to *narrowing resource loops* (that includes efficiency and has a life cycle perspective), which were not born within the CE concept and understanding, but need to be considered so that solutions are potentially circular *and* sustainable (column in the centre of the table);
- They should be looked at **holistically**, which means that rather than concentrating on a single strategy, readers or users of this module and related design for circular economy checklists should consider the different strategies, their **interdependence, and complementarity**;
- None of the strategies is a guarantee of sustainability; the implementation of a specific strategy or a combination of strategies will have **negative externalities and trade-offs** that need to be evaluated using life cycle thinking and addressed, preferably through innovation;
- These strategies concern both **product design and service design** and are mutually supportive; often, business models are mentioned because circular product and service design is intertwined with business models that companies adopt to put them into the market.

Table 4: KATCH_e design strategies for a circular economy, organized according to resource loops and phases of the life cycle they relate to

Phase	KATCH_e design strategies for a circular economy		
	Slowing loops	Narrowing loops	Closing loops
 Uphill			
 Tophill	– Design of long-life products (1) – Design for product-life extension (1) – Design of product-oriented services (2) – Design of use-oriented or result-oriented services (2)	– Design for materials sustainability (1) – Design for energy sustainability(1)	
 Downhill			– Design for recycling (1) – Design for remanufacturing (1)

Note: (1) product design; (2) service design

It should be noted that the strategies related to narrowing loops stem from the eco-efficiency paradigm and should always be used in combination with those from slowing and closing loops, as they are complementary. In other words, it does not make sense to design a long-life product without caring for the energy and materials (including water) sustainability along the life cycle. This idea is illustrated in table 4, where the KATCH_e strategies of design for a circular economy are distributed along a simplified version of the products' life cycle, also know as the "Value Hill" (Achterberg et al., 2016): (i) Up-hill - before use (encompassing extraction of raw materials, manufacturing, assembly and retail), (ii) Top-of-the-hill - during use and (iii) Down-hill - after use (including reuse, refurbish, remanufacture and recycling – and eventually final disposal). The table shows the most direct relationship, but one should keep in mind that potentially the entire life cycle is affected by each of the strategies – for instance, moving from a product to a service approach, although it concerns the use phase because the use/consumption model is changed, may lead to less products needed for the same function, which means fewer resources extracted and processed, less waste, etc.

3.2 Strategies for slowing resource loops

3.2.1 Design of long-life products

Currently, in most design projects the material efficiency component (that is, designing products with less material) is already considered as it is directly related to the costs reduction, thus being considered good commercial practice for companies (Bakker et al.). On the other hand, the product life and product recycling are not usually considered in a design project (Hatcher et al., 2011).

The feasibility of long-life products in a business context and the associated consequences for product design, have remained largely unexplored (Hollander, 2012) however there are several ways to extend the useful life (and value) of a product that designers should consider strategically in their projects.

The design of the products in this strategy has as the main goal, the durability of the product considering technological and emotional aspects in different levels. (Nancy Bocken 2016; Martijn Gerrittsen 2015).

At a technological level, the design should consider:

- the durability of materials and processes;
- the durability of components and the relations between components;
- the technical solutions that allow a physical performance of the product during a long time without the need for maintenance or repair actions;

At an emotional level, the design must consider the relationship between the product and the user for a longer time. This kind of solutions should consider aspects such as aesthetics, ergonomics, trust or value for money. Product attachment implies the existence of an emotional connection between a person and an object. When a person becomes attached to an object, he or she is more likely to handle the object with care, repair it when it breaks down, and postpone its replacement as long as possible. So, fostering a strong product-user relationship can lead to lengthening the life span of many durable consumer products (Schifferstein & Zwartkruis-Pelgrim, 2008). The highest levels of attachment are registered for recently acquired products (<1 year) and for products owned for more than 20 years. However, attachment is determined by multiple themes, many of which are circumstantial to consumers' experiences and therefore difficult for designers to control (Page, 2014). So far, different studies reveal that for new products, enjoyment and pleasure may be the main driver of attachment, whereas for old products memories may be more important. Appearance and reliability also have considerable influence on participants' attitudes towards replacement. Designers should create products that are both useful and enjoyable. This asks for products that evoke sensory and aesthetic pleasure.

Design criteria for long-life products include:
– Strong product-user relation – Durable and wear-resistant materials and components – Timeless and customized design – Reliability – Lifespan information to clients/consumers – User-friendliness

Example: Swiss army knife	
Lifetime warranty, high-quality materials, after-sales services, strong product-user relationship	
Source: www.swissarmy.com	

3.2.2 Design for product-life extension

Product life extension is an increase in the utilization period of products, which results in a slowdown of the flow of materials through the economy (den Hollander & Bakker, 2012).

Designers can and should incorporate features that enable products to serve their originally planned functions over a longer period without losing their performance or that can be maintained or even, upgraded to extend their life and maintain the attractiveness throughout time to its user. The extension of life is the counter-strategy to the implanted programmed obsolescence, in which the products are designed to lose part or all of their performance after a specific time.

This strategy is complementary to the promotion of a set of services linked to the product that enables the technological and emotional extension of the function of the product. The design of the product must, from the initial stages of the process, foresee that an action by the user or expert services can be applied in the product or components, to reset or upgrade the function for which the product was designed.

For the effectiveness of the strategy, the design process must take into account simple solutions for disassembly/assembly and modularity/standardization, to promote easy maintenance and repair, upgrade, and reuse of the product or components (Nancy Bocken 2016; Martijn Gerrittsen 2015). Designers have several different methods available to them for designing adaptable products, with product architectures that provide robust support for adapting products to meet changes in functional and environmental requirements, as well as advances in technology (Levandowski et al, 2015; Zhang et al, 2015).

According to Stahel (1998, p.29), the key to extending product life "lies in transforming an industrial economy focused on the real linear output to a service economy focused on the use of loops." In the background, this is a concise perspective of the thinking that the design practice has to move towards a circular economy.

In order to extend the life of products, design should consider the following criteria:

- Easy replacement of components
- Aesthetic and/or technical upgradeability
- Durable and wear-resistant materials and components
- Use of modular solutions
- Simplified product architecture
- Choice of tools needed for dis- and reassembly
- Minimize connecting elements
- Facilitate access and detection of connecting elements
- Standard connection elements

Example: Fairphone

Modularity, upgradeability, components available to the user, simplified disassembly

Source: www.fairphone.com

3.2.3 Design of product-oriented services

This strategy includes different types of services that prolong the lifetime of products. They concern consumer products as well as business-to-business situations. The business model is still mainly based on the sales of products, but some extra services are added (Tukker, 2004) (see the *KATCH_e **Business models** module*). For these services to be successful, products must be designed in such way that they are easy to disassemble, repair, maintain, refurbish, clean or upgrade. Often, these services are linked to the selling of consumables, spare parts, and add-ons to support the life cycle of long-lasting products (Achterberg et al. 2016). Since these services are additional to (and not replacing) the selling of products, the life cycle costs of the products are not retained by the provider, and thus the incentive to extend their lifetime at the maximum possible may not exist, unless if the client or consumer clearly rewards that or if the revenues related to repair or maintenance are significant. The sustainability potential of these services depends on the actual increase in the lifetime of the goods.

Services for a long life of products typically bring the following benefits:

- They are the most efficient way to retain or restore the system back to normal working conditions (Ajukumar and Gandhi, 2013);
- They are a source of competitive advantage and business opportunity (Armistead and Clarke 1992);
- They may generate more than three times the turnover of the original purchase (Wise and Baumgartner, 1999);
- They provide protection, pollution prevention, personnel safety and waste disposal (Ajukumar and Gandhi, 2013)

Examples of product-life extension services:

Maintenance, repair, refurbishment and cleaning services: e.g. repair cafes, services provided by the product manufacturing company (very common e.g. in the automotive and technology product firms, that in this way generate a fair percentage of their total revenues (Cusumano, Kahl, & Suarez, 2008), services provided by retailers, services offered by specialized companies.

Technological upgradeability: computers, telephone systems and copiers are examples of products prone to this type of services (Entrepreneur, n.d.) They can be offered by manufacturers, retailers and specialized companies.

Aesthetic/cultural upgradeability: examples of this service can be found in the furniture, apparel and decorative objects industries, mostly offered by small workshops. In the construction industry, on the contrary, aesthetic upgradeability is a very big business and often part of larger renovation works. Examples can be found in *Reuse and design – concepts and materials* (Galgani 2014).

Advice, consultancy and training concerning prolonging the lifetime of products. This can be offered by the product provider, by other companies or even by individuals, (a typical example are all the videos available on YouTube on “how to fix…” or “how to repair…” all kinds of appliances, cars, furniture, apparel, etc.).

Design criteria for this kind of services include:

- Geographic accessibility of services
- Variety of offers in terms of available services
- Customer satisfaction
- Added-value (for customers)
- Employment creation and good working conditions
- Transportation sustainability
- Involvement and promotion of local community

Example: Repair café

Promotion of repair, organization of repair workshops, sharing knowledge, tools available, strengthen social links.

Source: www.circulareconomy.pt

3.2.4 Design of use- or result-oriented services

In this strategy, the keyword is “ownership”. The provider retains the ownership of the product and makes it accessible to the clients (again, individuals or organizations) through different business models (Tukker, 2004). For the description of use-oriented services, such as leasing, renting and sharing, pooling, and result-oriented services, see subchapter 1.2. Here, the sustainability potential of the different types of services is discussed.

- **Leasing**: In terms of sustainability, this kind of services may be interesting if the provider may influence the design of the product since it is his/her own interest that the product lasts a long time. If the provider cannot influence the product design, the potential benefit relates to more efficient use of energy or consumables by better maintenance, repair and control. This service has tangible value for the user since various costs and activities are shifted to the provider.
- **Renting and sharing**: The sustainability potential can be high if the life cycle impacts are mainly related to manufacturing, as a less number of products may accomplish the needs of multiple users when compared to the traditional product ownership model. Renting and sharing may represent a significant effort by the user into getting access to the product, but the tangible benefit is related to not needing to bear the capital costs. Renting normally does not contribute to self-esteem or intangible experiences, except if the product-service combination is designed with that purpose (e.g. possibility to customize a rented car).

– **Pooling**: The access to the product may put even more challenges to the users then renting or sharing, related to the simultaneous use. On the other hand, the intensity of use of products is even higher and the benefits in terms of environmental impact can be significant, especially if the life cycle impacts of the product are related to the use phase.
– **Result-oriented services**: Like in the above types, the ownership of products is not transferred to the client; since all life cycle costs stay with the provider, he/she will try to find innovative ways to reduce costs and liabilities and has more room for manoeuvre to design a low impact system with high customer satisfaction. Examples of this strategy are the "pay per lux" service offered by Philips at Schiphol Airport, the "power by the hour" of service of Rolls-Royce engines in Boeing aircraft or Nor-Line vessels, or the "pay per mile driven" service (tires), by Michelin. Taking this last example: customers pay per miles driven; they don't own the tire and don't have to worry about maintenance are any problems that occur with the tires. On the other hand, Michelin has an incentive to design long-lasting tires and, by taking back worn-out tires, the company is motivated to design them so that they can be reprocessed into a valuable input for new tires or another product (Accenture, 2014).

Information and communication technologies (ICT's) have a very important role as enablers and facilitators of 'products as services': "they allow for establishing real-time information exchanges among users, machines and management systems. These technologies are intrinsically customer-focused and provide the information and connections needed to maintain a relationship far beyond the point of sale" (Accenture – circular advantage report). Examples of application are apps for sharing and pooling platforms, materials tracking in the built environment, etc.

The more intense the use of 'products as services' is, the more their potential to contribute to a CE is unlocked. Therefore, they should be easily accessible, add value to the customers and be designed and operated to achieve a high level of customers' satisfaction. Other considerations to render higher levels of sustainability relate to transportation and involvement of local communities.

Design criteria for these services are similar to the previous ones, but include specific topics, such as the influence of the service in product design and the existence of ICT:

– Accessibility
– Influence in product design
– Impact of the service in resources use intensity
– Existence of easy and affordable ICT - Information and communication technologies
– Customer satisfaction
– Added-value (for customers)
– Transportation sustainability
– Involvement and promotion of local community
– Employment creation

Example: Lime scooters	
Electric scooters renting service for urban mobility.	
Source: www.li.me	

3.3 Strategies for closing resource loops

3.3.1 Design for recycling

The objective of this strategy is to develop products in such a way that the materials ("technical nutrients") can be continuously and safely recycled into new materials and products (Bocken et al, 2016). Although in many cases recycling is one of the last strategies to consider in the development of products and services within circular economy, design for recycling is a strategy to be considered by design teams. Designers must understand the process and the conditions for efficient and quality recycling, resulting in quality materials that can be used as valuable input material in the product or service cycle. The potential of recyclability of a product can be enhanced by the easiness to disassemble the product.

Recycling is the process of recovering materials for the original purpose or other purposes, excluding energy recover. To establish a continuous flow of resources in the technological cycle, the "waste" resources are to be recycled into materials having properties equivalent (or even superior, in a process, called upcycling) to those of the original material (Bocken at al., 2016). In the majority of nowadays recycling operations, what occurs is downcycling (reprocessing into products requiring lower properties), which does not enable a circular flow of resources, but only delays the linear flow of resources from production to waste (McDonough & Braungart, 2002).

Design for recycling aims at designing products which materials that can be recycled without property losses (and therefore endlessly, in theory).

As for the use of recycled materials in the product, that is part of the quality of input materials and is addressed in strategy Design for materials sustainability.

Design for recycling should contemplate the following criteria:

- Choice and variety of materials for easy recycling
- Marking of materials for recycling
- Easy separation of technological from biological materials
- Minimize connecting elements
- Facilitate access and detection of connecting elements
- Standard connection elements
- Avoid the use of dangerous tools and processes
- Employment creation and good working conditions

Example: Ecotech Tile

Floor tile produced with recycled materials from internal production

Source: www.revigres.pt

3.3.2 Design for remanufacturing

Through remanufacturing, a used product returns to a "like-new condition"; it is a process of recapturing the value of the material when a product was first manufactured. Remanufacturing results in the reduction of energy and material consumption, and of production costs (Gray & Charter, 2007), allowing the manufacturer to increase the productivity as well as the profitability in the business. (Fegade, Shrivatsava, & Kale, 2015)

Remanufacture can offer a business model for sustainable prosperity, with reputed double profit margins alongside a significant reduction in carbon emissions and the energy required in manufacture.

The potential or remanufacture is affected by the physical characteristics specified during the design phase, like the complexity and modularity of the products, the possibility to maintain or adapt technologies, the quality and durability of the materials and the solutions adopted in the product, etc. Design for Remanufacture is enabled by business models which recognise the benefits of remanufacturing and services like reverse logistics which allow that the products return to the factory at an affordable cost.

Remanufacture views end-of-life products and components as a resource. Promotion of remanufacturing can, therefore, benefit both the economy and the environment. Design for Remanufacture can optimise the process of remanufacturing, increase the practice of remanufacturing and therefore increase the significant economic development opportunities for businesses and people.

This strategy also avoids that valuable material materials and components ends low valued valorisation or in a landfill and creates a market for skilled employment and, in principle, is preferable to recycling. The value of materials and components is maintained by returning products to working order, whereas recycling simply reduces the used product to its raw material value (Ijomah, McMahon, Hammond, & Newman, 2007).

Although in theory any product can be remanufactured, the business case, which would make remanufacture economically feasible, varies between sectors and products, and the integration of other considerations like design for disassembly, which enables the process. Design for remanufacturing optimizes remanufacture through consideration of both the business model and the detailed product design and must be considered in the initial design of the product (Gray, 2007).

The following criteria should be considered in design for remanufacturing:

- Technology integration/stable technologies over the lifetime
- Use of modular solutions
- Existence of a take-back system
- Optimize reverse logistics (RL) network and involve the supply chain in RL planning
- Durable and wear-resistant materials and components
- Simplified product architecture
- Minimize connecting elements
- Facilitate access and detection of connecting elements
- Standard connection elements
- Employment creation and good working conditions

Example: Cannon refurbishment program

Refurbished products with comprehensive quality assurance inspections, replacing parts showcase the company’s dedication to product excellence

Source: https://shop.usa.canon.com

3.4 Strategies for narrowing loops

3.4.1 Design for materials sustainability

The selection of materials, (including water and components) and the quantity of material used, are key elements in the definition of the potential impact of a product or a service. In the design phase, the design teams can choose materials and components with lower impact by itself, or that have a positive influence on the product or service systems and can adopt measures to reduce the number of materials used by implementing efficiency strategies in the design. Decisions taken in the conceptual design phase are fundamental to influence the efficiency and optimization of material consumption in the life cycle of the product or service.

It is difficult to fully describe what a sustainable material is. It depends not only on the materials but the conditions in which it is transformed, applied and used. However, we can affirm that sustainable materials are ones that have a lower embodied energy as well as a lack of emissions, waste and making sure that the material continues to be created or grown rather than deplete its stocks.

Another way to describe them can be by looking at them as the materials whose use achieves environmental benefits, unlike other conventional materials.

Apart from the reduction of resource consumption, other strategies, influencing the efficiency in the life cycle can be adopted. Optimizing resource cascading can be an option to prolong the lifecycle of resources.

Resource cascading is the sequential exploitation of the full potential of a resource to improve resource efficiency. Resource cascading allows for significantly extending a resource’s useful life through repeated utilization. This approach to production and consumption states that energy recovery should be the last option, and only after all higher-value products and services have been exhausted.

This concept is often associated with the forestry sector, in which cascading use can be effectively demonstrated.

Several sustainability issues must be considered in the selection of input materials and components that constitute the product or that are necessary to provide the product-service. Are the materials hazardous, non-renewable or scarce? Are they virgin or recycled? Can they be recycled? Do suppliers have good environmental and social practices? Are the materials and components local, or do they have to travel long distances and do not support the local or regional communities' economies? Based on the materials and components used in the product or product-service and the processes necessary to manufacture them, the possibility of using alternative ones with better environmental, social and economic performance must be analysed.

Designers who can develop solutions to fulfil the needs of the users using less and more sustainable resources (materials and water), have a higher potential to succeed in the creation of more circular and sustainable solutions.

The following design criteria apply:

- Optimize products' design (shape, size, weight, etc.) to reduce material consumption
- Avoid consumable components and materials in the use phase
- Use of recycled materials
- Eliminate the use of toxic materials in the product
- Promote the use of renewable materials in the product
- Use of locally produced raw materials and components
- Avoid the use of scarce and/or critical materials and promote the use of abundant materials
- Use of raw materials and components from suppliers with good social responsibility practices
- Information on product sustainability to consumers
- Influence sustainable consumer behaviour regarding consumables in the use phase

Example: Corks products

Cork is a material of vegetal origin from the bark (*suber*) of cork oaks (*Quercus suber)*, light and with great insulating power

Source: www.amorimcork.com

3.4.2 Design for energy sustainability

Like in other areas, product design should take into account the energy that the product will need to meet user needs, taking the whole life cycle into account. For energy-using products (e.g. electronics, cars, lighting), the use phase may be the most important one; however, for many other non-energy consuming products (such as furniture or packaging), the manufacturing phase can represent a significant portion of energy consumption.

Another emerging area is related to technologies in the field of renewable energy, such as small fuel cells, flexible photovoltaic solar cells and human power. As renewable energy sources develop and become smaller and more flexible, possibilities of integrating them into the product design have emerged. However, until recently, renewable energy technologies have been more or less "pasted" upon the products instead of being integrated into the design of the product. It is a big challenge to find the appropriate products or functions for these new technologies and to integrate them into the total design of the product (Mestre & Diehl, 2005).

This strategy thus encompasses energy efficiency in the various stages of the life cycle through design options, the use of solutions that incorporate renewable energy and influencing consumer behaviour regarding energy consumption.

The related design criteria include:

- Reduce energy consumption in production
- Reduce energy consumption in use
- Reduce energy consumption in transport
- Energy plus
- Replace non-renewable by renewable energy
- Use low embodied energy materials
- Information on energy consumption to clients/consumers
- Influence consumer behaviour regarding energy consumption

Example: SunPack

A backpack with a removable solar charger.

Source: www.kickstarter.com/projects/flexsolar

Assignment 5

Select two strategies and search for examples of products or services that correspond to those strategies.
Describe the examples using the same criteria as in the chapter and discuss the overlapping and complementarity between strategies.

Assignment 6

Read the following product features and identify the CE design strategy(ies) that best fit with them:

1. A textile upholstery for sofas made with 100% recyclable textile.
2. A durable kitchen worktop material.
3. An easy to repair kitchen worktop material.
4. Leasable furniture.
5. An armchair frame made with wasted wood generated in the manufacturing of ships
6. Furniture for kids that grow with the child.
7. A modular windows frame design that is capable to adapt to future changes: bigger windows or need to partial replacement of the window frame.
8. Wall shelves made with disposed doors.
9. A modular sofa able to be enlarged and assembled in different ways to adapt to new spaces or layout changes.

4. Product and service design step-by-step

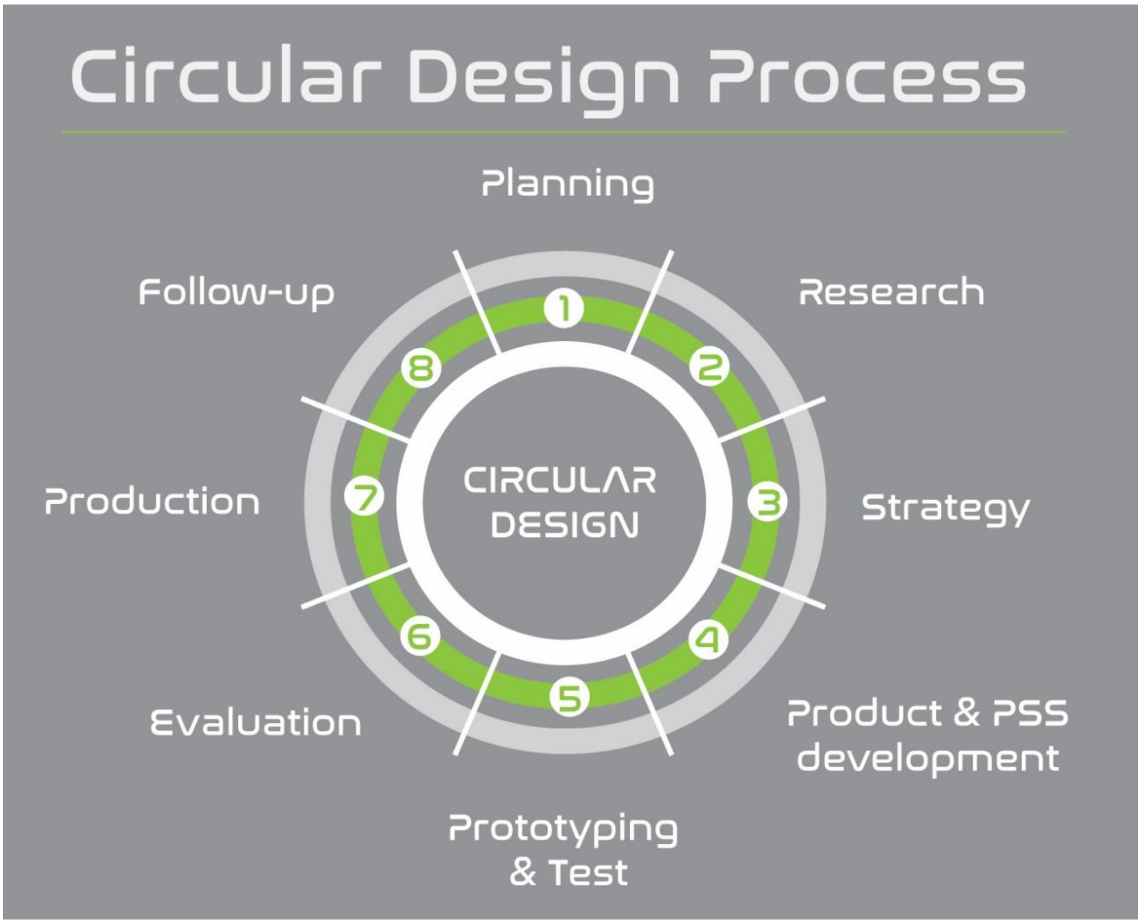


Figure 6 – Product-service development step-by-step

Design for circular economy, or circular design (as does design in general) has the responsibility to solve product or service problems, integrating several criteria in problem-solving in an innovative way and adjusted to the needs of users. In the circular economy, the designer has the function of translating the strategies and concepts of circularity in the development of products, services and systems that promote the transition from a linear model to a circular model focused on the closure of cycles, in the efficiency and sustainability of the entire system.

A design process is a method that leads to the conceptualisation and creation of the future, by developing new things that do not exist; design interacts and changes the world and society. The innovative solutions cannot be predetermined but the methodology used to develop solutions can be more predictable in accordance with the innovation level required and desired for the project.

For product design, the methodology has been defined by now and has been supported by several tools, widely adopted. Circular services have a higher potential for sustainability if developed with sustainability criteria and are based on business models which deliver added value to products and services that meet the needs of users in a more sustainable and circular way. These services are capable to meet the needs of users in a more sustainable way and to deliver more value to the customer and companies focusing on new and circular business models. In these systems, the focus is on the service that the user receives from a product and on the way he/she uses a product's function, rather than on the product itself.

Circular products and services are a challenge and at the same time an excellent opportunity to innovate at a higher scale in multidisciplinary teams – in which designers have an important and strategic role and hereafter are designated as design and development teams. However, services are more complex than products and their design and development implies using several methods. These complex scenarios imply holistic methods and approaches of design thinking, which sometimes do not begin with a fully defined or stabilized brief. The integration of a circularity perspective in the system is also a challenge that designers have to deal with. Several approaches can be applied, and the process will depend on the problem addressed, the companies involved, the design teams, the stakeholders and many different factors linked to the system. (UNEP, 2009)

The development process for circular services includes a smart combination of product design and service design. The design and development teams have more degrees of freedom in addressing the system's functionality than usual. This implies a wider range of responsibility but also a wider scope of opportunity (Müller and Blessing, 2007).

Several methods and definitions are available in practice and literature. In this module, we propose a structure for the design practice for circularity that is based on the design for sustainability process that has been widely applied and validated in numerous projects worldwide.

Although the idea of a process implies a linear sequence of events, this can be misleading (Kumar, 2013). According to their nature, many projects are actually non-linear and promote iterative processes.

Innovative and circular design processes start on a full understanding of the context of intervention by creating abstractions and conceptual models that help us to reframe the problem in new ways. After that, we explore new concepts in abstractions to evaluate them before their implementation in the real world. This promotes a thinking approach between real and abstract. Through a process of analysis and synthesis during the abstract stage, we engage the process of realization proposals leading to the realization of the proposal with the goal of its implementation, passing from the abstract understanding to the making for the real context (Kumar, 2013).

The methodology is based on eight general steps that should be adjusted to each particular project. The steps firstly describe the work performed in product design, in this case having in mind circular design. Then, the description of services design follows, highlighting when needed the related specificities.

Step 01 – Planning of the project

The first stage of the circular design process concerns understanding the context of the problem that the design and development team has to solve. The problem definition will help the designers to generate a holistic understanding of the context and gather great ideas to establish features, functions and any other elements that will allow them to solve the problems.

Often, projects start without a proper plan, with a poor definition of objectives and without a commitment from key elements, such as top management, project teams and other *stakeholders*. The definition of the brief for the circular design project is also an objective of this step. The brief is a well-known element by all project teams but often underestimated.

Step 02 – Needs analysis – research

In this step, the relevant baseline information concerning the need or opportunity that emerges from the previous step has to be gathered and analysed so that the circular strategies for the new solutions are appropriately defined based on a solid rationale. The main objectives are to determine the circularity, environmental, economic, social and market aspects of the reference product, to identify the "hot spots" in the life cycle, in dialogue with the stakeholders, to identify legal requirements applicable to the new solutions, and to adjust or modify the brief defined in the previous step, if needed. For a circular service, it is fundamental to increase the system's boundaries and analyse the functions that need to be fulfilled and the requirements and drivers from stakeholders for the circular service.

Step 03 – Definition of the circular design strategy

This step aims at identifying and selecting the most promising circular and sustainable design strategies for the product or service (see chapter 3).

The strategies help the development teams to (i) analyse the circularity and the life cycle of the reference product/service and (ii) to identify improvement options for new concepts. For a circular product or service, defining the strategy includes the identification of functions and target specifications for the new solution. For the circular service, it is necessary to define the value proposition and performance standards. A global approach for validation along with the several project stakeholders is relevant to ensure a solid project definition.

Step 04 – Product and PSS development

The development of a new concept has two distinct moments. The divergent thinking moment, in which several possible ideas are created, and a second moment, the convergent thinking moment in which the ideas are refined and narrowed down to the best idea. In order to discover which ideas are best, the creative process is iterative. This means that ideas are developed, tested and refined several times, with weak ideas dropped in the process. The selection of the best idea to be further developed must include an evaluation of its circularity and sustainability potential.

At this point, the team should have the needed circularity and sustainability information from the previous steps to support the development of a new and more sustainable product or service.

During the development phase, the whole system, the stakeholders and all the interactions must be clarified and established, and the relations between the physical products and the service components must be developed and detailed.

Partnerships with stakeholders have to be established, specific products may need to be developed and/or purchased, the system structure has to be defined, the interface and software has to be designed, adjusted or purchased and the promotion and communication need to be developed and implemented.

Step 05 – Prototyping and testing

The prototype is generally used to test and evaluate the new solution and to provide specifications for a real, working system rather than a theoretical one. The goal of a prototype is to test products and services' ideas before the development of the final solution, including the test of the circularity and sustainability potential.

Prototyping is essential to identify and resolve several issues before launch. It can also reveal areas that need improvement, allowing the development team to go back and adjust the initial concept.

Step 06 – Evaluation of the new product/service and of the project

This step aims to analyse the circularity and sustainability performance of the product and/or service against the defined objectives and the effectiveness and procedural aspects of the project. Firstly, the company should consider whether the process used for the project is actually appropriate, and secondly, the company should evaluate the new product or service having as a basis the objectives defined in the brief. Apart from circular and sustainability aspects of the new product or service, functionality and technical qualities should also be evaluated during this phase.

Step 07 – Production

If the new circular product or service has a good evaluation, the company can start the production and placement in the market.

To guarantee the circularity of the system, all aspects of production and placement of the product/ service have to be considered and aligned with the previous steps. To attain a higher degree of circularity and sustainability, it is essential that the entire company (and relevant potential stakeholders involved in co-design) follow the process.

For this purpose, it is also important that the company performs an internal promotion of the procedures and process of the new product or service, also with the promotion and commitment of relevant stakeholders.

Step 08 – Follow-up activities

The company must define follow up activities after having made an evaluation of the product or service and the project, as described in the previous steps. Follow-up activities should promote a circular approach to project development based on a continuous improvement idea.

Assignment 7

- Think of a furniture product to be redesigned in a circular design project.
- Consider the eight steps of the project:
  1. Planning of the project
  2. Needs analysis – research
  3. Definition of the circular design strategy
  4. Product and service development
  5. Prototyping and testing
  6. Evaluation of the new product or service and of the project
  7. Production
  8. Follow-up activities
- Identify at least two tasks in each step to align your project with circularity and sustainability.

5. Design for CE in the construction sector

In the previous chapters, a generalist approach was taken when describing the strategies and methods for product and service design for circular economy. However, the construction sector presents specific challenges that will be discussed below.

It is important, however, to clearly state the scope of this module. Firstly, there are some distinctions to be made: are we talking about building design (i.e., the domain of architects, engineers, contractors, investors, and users) or about construction products design (i.e., the domain of designer and manufacturers)? This chapter focuses on the latter, but it is impossible to think of "circular construction products" without relating to the building into which they are incorporated. As Geldermans and Jacobson (2015) put it, when it comes to sustainable construction, products need to fulfil **intrinsic properties** (high quality, of sustainable origin, non-harmful and consistent with biological and technological cycles) as well as **relational properties** (i.e., how the product relates to the design and use of the building anticipating multiple future user scenarios), such as dimensions, connections and life span. The **circular value** of products for the construction industry is, according to those authors, in the **intersection of those properties** (figure 7).

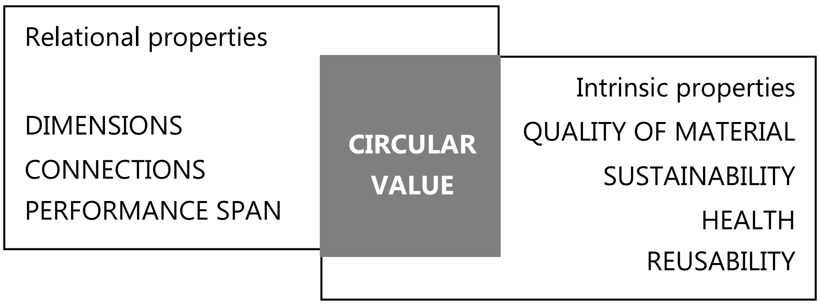


Figure 7 – Circular value as the intersection of relational and intrinsic properties of building products. (Geldermans and Jacobson, 2015)

Buildings are a dynamic set of subsystems (Geldermans and Jacobson, 2015) in which different circular economy strategies vary in applicability (e.g. the lease concept may be uninteresting for a whole building due to its very long life span, but may be feasible to elements with a shorter life span (Evert, S., Crielaard, M., Mesman M., (2015). Brandt's layers of change (site, structure, skin, services, space plan and stuff) help in working out those differences (figure 8).

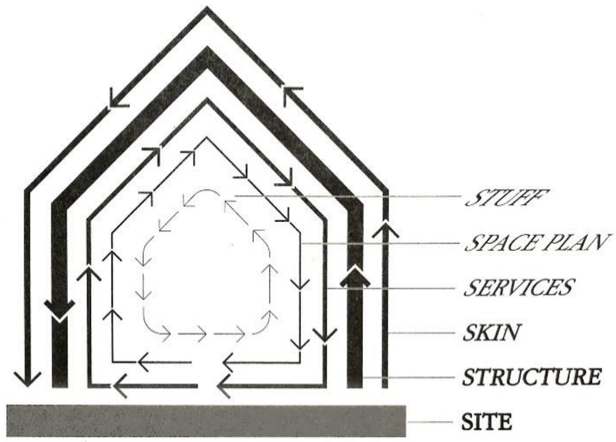


Figure 8– Six dynamics that characterise a building, according to Stewart Brand. (Brand, 1994)

The layers and respective lifespan are (Brand, 1994):

- Site: the geographical setting, the urban location and the legally defined lot
- Structure: the foundation and load-bearing elements (30-300 years)
- Skin: exterior surfaces (20 years)
- Services: working functions of a building, e.g. communications and electrical wiring, plumbing, sprinkler system, HAVAC Heating, ventilating and air conditioning) and moving parts like escalators and elevators (7-15 years)
- Space plan: interior layout (3-30 years)
- Stuff: all non-fixed furniture, i.e. things that twitch around more frequently

In a circular economy, it is crucial that a building does not lose its utility over time. To this endeavour, it is necessary to focus on **building design for adaptability**, **building design for relocation and building design for deconstruction and reuse** (Potemans, 2017). What does this mean for the construction materials and products, keeping in mind the building layers as defined by Brandt (1994)? The following design approaches apply, based on the work of Schut et al. (2015) and Geldermans and Jacobson (2016):

- **Minimize materials' use**: the most effective way to prevent it in construction sites is to use existing buildings or reuse materials and elements and industrially pre-fab construction elements (Schut et al., 2015).
- **Intelligent dimensioning** given the planned function, performance and lifespan. This seems to be a contradiction with the previous point, but the goal of facilitating changes in the future may imply over-dimension, even if this means a surplus of material consumption; in the total lifespan of a building it can prove beneficial if the amount of material demand for adaptation is reduced (Geldermans and Jacobson, 2016);
- **Modular design**: an optimum life is assumed for parts of a building, and the goal is to replace building sections by modules (off-site manufacturing) effectively and efficiently (Schut et al., 2015);

- **Design for deconstruction**: designing construction elements in such a way that they can be taken apart ("LEGO approach");
- **Design for high-quality future reuse and recycling**: in the context of CE, this means not only in one cycle, but with a longer time frame in mind – second, third, etc. lives; this requires good quality recycling, or upcycling following principles of design for disassembly and flexibility (Schut et al., 2015; Geldermans and Jacobson, 2016).

Circular economy is also about dematerialization and renewable energy sources. This requires:

- **Designing services** such as infrastructure sharing, co-housing, co-working, etc.;
- Designing construction elements that allow the use of solar, wind, biomass and other **sources of renewable energy**.

Assignment 8

a) Observe the room you are in (classroom, office room, at home, etc.).
b) Define a different use for the room in 20 years' time (for instance, the room will be a dance room because the building's purpose will change into a performing arts centre).
c) Identify one element of the space plan and stuff layers (according to Brand) that will need to be adapted for the new purpose and discuss design options for this element according to the eight KATCH_e design for circular economy strategies.

6. Tools for product and service design for CE

6.1 KATCH_e Tools

6.1.1 CE Designer

What is the tool for?

The CE Designer is a semi-quantitative tool for prioritization, assessment and idea finding of circular solutions for product and/or service (re)design. The tool is e organized according to 8 strategies that address the most relevant issues a design team needs to consider in the development process of new products or services to support the transition to a more circular society.

What is the information needed before using the tool?

The user should have a good knowledge of the sustainability profile of the reference product or service along the life cycle or be provided with such information (in the case of the tool being used in an academic context). Previous knowledge about CE and the strategies is recommended.

What results can be expected?

- A prioritization of applicable design strategies for a more circular and sustainable product/ service;
- The analysis of a reference product or service according to the chosen design for circular economy strategies;
- Immediate improvement ideas and opportunities, through the reflection and assessment of each strategy and related criteria;
- Background information for a brainstorming or other creativity session;
- A graphic comparison between the reference product or service and the new one(s). With this feature, the team can communicate where and how the new solution performs better.

How is the tool used?

Prioritization of strategies: The user evaluates the importance of each of the 8 strategies according to the requirements of the project, the company and its business strategy, etc. and selects the ones that should be assessed in the next phase.

Assessment:

- **Step 1**: for each strategy selected, the user indicates the importance of each criterion. By default, all are rated as very important.
- **Step 2:** the user evaluates each applicable criterion with an ABC scoring system. The weighted sum of the performance of all criteria results in the final score of the strategy for the reference product/service. The Score A means that the criterion is fulfiled by the current solution, the B means that it is partially fulfilled and there are opportunities to improve and, C, means that the criterion is not fulfilled, and that is a hotspot of the reference situation that should be improved if possible.

– **Step 3**: the user inserts improvement ideas or measures linked to each criterion. This can be used in a brainstorming session after filling the tool for the reference product or service. After the filling in of all relevant strategies and related criteria, the user can go the results spreadsheet, in which a chart with the score of the strategies and the information resulting from the analysis are displayed. This information may then be used to support a creativity session to define a new concept for a product and/or a service.

– **Step 4:** After the development of a new product and/or service, the analysis according to what was described in step 2 is repeated. This will allow a comparison between the reference situation and a new one, also displayed graphically in the results area.

6.1.2 CE Journey

What is the tool for?

This tool supports the players and/or stakeholders to assess the overall Product / Service / System journey, in the three stages (uphill, top hill and downhill) according to with several factors: materials, producers, stakeholders and users. Through a visual representation of the journey, it aims to identify the touchpoints between the factors identified: materials, producers, stakeholders and users, providing a model for analysis and identification of opportunities to optimize the journey and to enhance the closing of the loops to present a more circular solution.

What information is needed before using the tool?

The user should have a specific product/service in a specific context (materials, producers, stakeholders and users) in mind, which is then analysed further.

What results can be expected?

A visual canvas that allows you to see the journey and touchpoints of the products, producers, stakeholders and users to optimize the journey and closing of the loops.

How is the tool used?

– **Step 1.** Print all the cards and canvas and gather necessary materials per group.

– **Step 2.** Gather the group/groups in a room and explain the activity, tasks and overall goals.

– **Step 3.** Identity each participants role and link them with the possible cards and material(s).

– **Step 4.** Introduce task by task:

  - **1st SUPERPOWERS -** Identify major actors and resources in terms of materials, producers, partners and users;
  - **2nd CHALLENGES -** Each actor should get familiar with the different types of challenges and resource in terms of materials, producers, partners and users;
  - **3rd JOURNEY Canvas -** In collaboration, participants must fill the canvas based on the journey identified, where they must try to identify their touchpoints. Aim for optimizing the solution in its economic, environmental and social dimensions.

    During the process, always keep in mind the Circular Economy focus (purple card).

– **Step 5.** In the end, you can redo the canvas aiming to optimize the solution in order of: closing loops, waste as resources, assets sharing and feeding loops.

6.1.3 KATCH_UP board game

The objective of this game is to stimulate the users to generate value ideas from a business challenge, applying circular design and circular business strategies. The game acts as a guide to get an idea about an innovative product-service or to solve a real business problem and generate improvement opportunities.

What information is needed before using the tool?

No previous knowledge of circular economy is required, however, having knowledge about CE design and business strategies are preferred, as the application of the tool will be more agile, efficient and effective, leading to better-defined ideas.

What results can be expected?

Creation of a product-service idea applying circular design and circular business strategies to solve problems from case studies or your own company issues.

How is the tool used?

This tool can be applied under different situations: Company, academia and workshops. When this game is played in companies, real cases can be applied, i.e., to a specific product-service category and to solve specific company challenges. When this game is played in classrooms or workshops, the game offers hypothetical contexts to work on them.

PREPARATION: Form groups of 3-4 people and prepare the board and its elements

PLAYING: The game has 6 basic steps:

- **Step 1.** Problem context:
    - Presentation of the product-service category, business challenge and target group;
- **Step 2.** Way to the solution:
    - Presentation of the design for circular economy strategies that can be used to deal with the problem context;
- **Step 3.** Idea creation:
    - Development of the innovative idea that will solve the initial problem;
- **Step 4.** Business model:
    - Definition of the most appropriate business model;
- **Step 5.** Market launch:
    - Definition of how your product-service will be launched to the market;
- **Step 6.** Presentation and scoring:
    - CE ideas got as a result of the game should be pitched by the groups and scored using a Likert scale (1-5).

6.2 Other tools

Tool	Description	Source
Circular Economy Toolkit	The Circular Economy Toolkit is a free resource for businesses to find opportunities in the Circular Economy. With the vast number of possibilities for creating value out of the Circular Economy and cradle-to-cradle thinking, it can be challenging to assess all the options. The Circular Economy Toolkit has consolidated all the opportunities and provided information on how your company could start finding benefits. The Assessment tool offers a questionnaire to evaluate circular strategies and besides the assessment features, the tools provide useful information in each strategy.	http://circulareconomytoolkit.org/Assessmenttool.html
Material Circularity Indicator	The Material Circularity Indicator measures how restorative the material flows of a product or company are, and includes complementary indicators that allow additional impacts and risks to be taken into account. The indicators may be used by product designers, as well as for internal reporting, procurement decisions, and the evaluation or rating of companies. The Material Circularity Indicator for a product measures the extent to which the linear flow has been minimised and restorative flow is maximised for its component materials, and how long and intensively it is used compared to a similar industry-average product. The MCI is essentially constructed from a combination of three product characteristics: the mass of virgin raw material used in manufacture, the mass of unrecoverable waste that is attributed to the product, and a utility factor that accounts for the length and intensity of the product's use.	https://www.ellenmacarthurfoundation.org/assets/downloads/insight/Circularity-Indicators_MCI-Product-Level-Dynamic-Modelling-Tool_May2015.xlsx

Tool	Description	Source
Circularity Check	The Circularity Check is a self-assessment tool without external verification. The Checklist consists of a free questionnaire of about 60 questions that can be filled out online. It is meant to assess if a particular product/service is "circular", and if so how circular. The basic idea is to first look at the circular economy aspects used and then perform a sustainability check. For each circular economy aspect used in your product/service, scores are acquired. The higher the scores the better, but you can get them in many different ways. Red flags are raised if you score zero on one of the phases of the value cycle, or on sustainability. Is the product circular and sustainable, and if so, to what extent? A score is assigned to each question. The higher the score the better. The outcome of the check is a % that indicates how circular your product/service is. The tool also provides partial scores on design/ procurement/ manufacturing, delivery, use, recovery, and sustainability. The Circularity Check is primarily intended as a product-based tool for self-evaluation by companies, from SMEs to multinationals.	https://www.wesustain-esm.com/circularity-check/main.html/?page=SUB_HOME&portal=1680lbeg

Assignment 9

Exercise with the CE Designer:

Using a specific product, service or problem, apply the tool to analyse the circularity profile and identify improvement measures according with the results of the tool. The following example of the coffee machine can be used as a basis to perform the exercise (the product and data were developed for the exercise and are fictitious).

<table>
<tr><th colspan="2">Reference product – Coffee machine</th></tr>
<tr><td>
</td><td>Lifetime – 10 years
Capacity – 0,5 L (equivalent to two cups)
Use – Average 2x/day

Production:
Produced and assembled in Europe
Heating components made in Asia
Materials of the body – PP and glass (pot)
Packaging – Single use, made with cardboard, EPS and LPDE
Certifications – ISO 14001 and SA 8000
Electric cables in PVC and copper
Use:
High consumption of energy, mainly to maintain the temperature of the coffee
End-of-life:
50% disposed in electronic equipment waste containers for valorisation (aware consumers)
50% disposed in common urban waste containers (non-aware consumers)</td></tr>
</table>

Exercises with other tools:

Use the same product and data and apply it to the other tools presented in chapter 6. Compare and discuss the results attained with the different tools.

7. Examples

REVICONFORT			
Description	REVICONFORT is a porcelain stoneware flooring for interior areas, public or residential, removable and reusable, quick and easy to apply. It does not require adhesives, cement or specialized manpower and can be used immediately after application. It is a versatile, innovative solution in the ceramic world, which revolutionizes the concept of fixed flooring. REVICONFORT brings together, in a single product, the technical characteristics of porcelain stoneware, the economic advantages of a simplified placement, the profitability of time in its placement, ease of mobility, ease of use and easy maintenance.		
Organization and country	REVIGRÉS, Portugal		
Sources	Company Website: ww.revigres.pt		
Images			
Images' source or credits	Revigres	http://revigres.pt/wp-content/uploads/2018/02/CAT_REVIGRES_PRO_2018.pdf	
Circularity approach(es)	Slowing loops Narrowing loops	**Sector**	Construction
Related Strategies	Design of long-life products Design for product-life extension Design for materials sustainability		

ClickBrick

Description

The Clickbrick system is designed for reusability and a long life without maintenance. The bricks are dry stacked, assembled with steel clips, without using mortar. This results in fewer materials being used with an inherent ventilation system avoiding moisture. Whereas traditional bricks are usually at best downcycled at their end of life, the ClickBricks can be disassembled and reused for the same purpose.

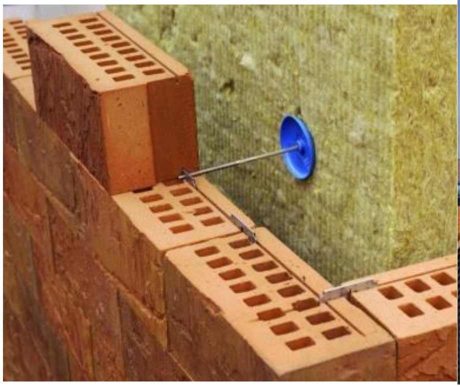
Organization and country

Daas Basksteen, The Netherlands

Sources

Company Website: http://www.daasbaksteen.com/en/Facade-systems/ClickBrick/page.aspx/67
http://www.zi-online.info/en/artikel/zi_2011-03_ClickBrick_for_a_wall_without_joints_1090523.html

Images



Images' source or credits

http://wiki.bk.tudelft.nl/mw_bk-wiki/images/thumb/2/22/Monsterkast_168_1.jpg/400px-Monsterkast_168_1.jpg

http://www.c2c-centre.com/sites/default/files/styles/v2-single-page/public/clickbrick.jpg?itok=rss7Dko

Circularity approach(es)		Sector	
	Slowing loops Narrowing loops		Construction

Related Strategies

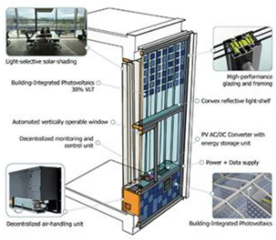
Design of long-life products

Design for product-life extension

Design for materials sustainability

Design for energy sustainability

Façade Leasing

Description	An interdisciplinary research team within the Faculty of Architecture and the Built Environment developed a circular business model based on the use of multifunctional façades as performance-delivering tools. Under this scheme, the client is no longer the owner of the building envelope and its integrated building services, but instead leases them from a service provider through a long-term performance contract. Rather than purchase the façade panels as a product, the client hires the energy performance and user comfort services delivered to his building by this new façade system.
Organization and country	TU Delft, The Netherlands
Sources	https://www.tudelft.nl/en/architecture-and-the-built-environment/research/projects/green-building-innovation/facade-leasing/facade-leasing-pilot-project-at-tu-delft/
Images	 
Images' source or credits	https://d1rkab7tlqy5f1.cloudfront.net/BK/Onderzoek/Projecten/RTEmagicC_Facade_Leasing_pilot_project_TUD_Panel2_Breakdown.png.png https://d1rkab7tlqy5f1.cloudfront.net/_processed_/8/9/csm_Leasing_facade_d6c5c7fb68.jpg
Circularity approach(es)	Slowing loops Narrowing loops
Sector	Construction
Related Strategies	Design of long-life products Design for product-life extension Design of use- or result-oriented services Design for materials sustainability Design for energy sustainability

Treehouse Riga - Jular

Description

Treehouse Riga is a modular home that can be easily adapted to the owner's needs. It is a prefab home, with less construction waste as compared to traditional construction methods, and expanding it to accommodate a growing family, for example, is a breeze.

The basic version of Treehouse Riga measures 474 sq ft (44 sq m) and features two bedrooms. It is made of just two modules. Each module measures 236 sq ft (22 sq m) and they are joined together in an offset way, which creates exterior spaces that slightly are different from each other. Presumably, more modules can simply be attached to the home, to create additional spaces such as extra rooms, a studio, a second bathroom and so on.

Organization and country

Jular, Portugal

Sources

www.jular.pt | https://www.treehouse.pt/construcao-modular/

Images

Circularity approach(es): Narrowing loops

Sector: Construction

Related Strategies

Design for materials sustainability

Design for energy sustainability

Remade – G64-R office chair

Description	Products that are reaching the end of their commercial life span are now being given a second chance, thanks to Orangebox Remade. The first product to be offered under this initiative is the G64, a very successful and durable office chair. 98% of the G64-R's parts are recyclable, with removed components either being kept for reuse or returned for material reprocessing. With a recycled content of around 80% (by weight), each remanufactured chair delivers a 60% reduction in CO2 emissions and saves 75% of water consumption compared to new.
Organization and country	Orange, UK
Sources	www.orangebox.com | https://www.orangebox.com/about/responsibility/remade
Images	
Circularity approach(es)	Closing loops Narrowing loops Slowing loops **Sector** Furniture
Related Strategies	Design of long-life products Design for recycling Design for remanufacturing Design for materials sustainability

Stokke Care Changing Table

Description	This design converts the changing table into a practical desk. It prolongs the use of the nursery product as the child grows, as it can be used as a place to play, draw or do the homework. Easy assembly.		
Organization and country	STOKKE AS, Norway		
Sources	www.stokke.com | https://www.stokke.com/en-za/164103.html		
Images			
Circularity approach(es)	Slowing loops Narrowing loops	**Sector**	Furniture
Related Strategies	Design of long-life products Design for product-life extension Design for materials sustainability		

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