Design for circular economy

This document is an executive summary of work performed in work package 1, task 4 "Design for circular economy" in the Horizon Europe project "IRISS". In short, IRISS aims to transform the Safe-and-Sustainable-by-Design (SSbD) community in Europe and globally towards a lifecycle approach, where safety, climate neutrality, circularity and functionality are integrated already in the designing and manufacturing phase.

SSbD is a key component of the European Commission's Chemical Strategy for Sustainability and it is a pre-market approach that aims to integrate chemical safety and sustainability as early as possible in the innovation process of a product and material. The concept of SSbD aims to ensure that chemical, materials and products are designed, produced, and used in a way that does not harm people nor the environment throughout a product's entire lifecycle.

In many ways the aim of SSbD overlaps with that of circular economy (CE) and therefore inclusion of CE aspects in SSbD is integral for its success. One of the most adapted definitions of CE is from the Ellen MacArthur foundation (EMF)[1] which describes a circular economy as *"an industrial system that is restorative or regenerative by intention and design. It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models"*[2]. The vision of EMFs circular economy is depicted in the butterfly diagram in Figure 1.

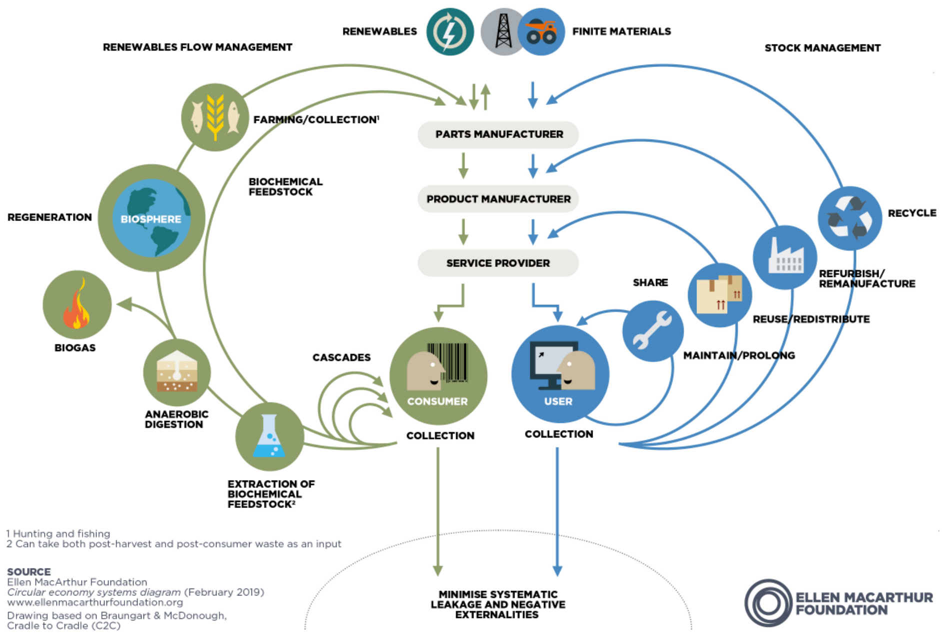

Figure 1 Ellen MacArthur foundations circular economy diagram[3]

[1] Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling*, 127, 221-232. https://doi.org/10.1016/j.resconrec.2017.09.005

[2] Towards the Circular Economy: Economic and Business Rationale for an Accelerated Transition, Volume 1, Ellen MacArthur Foundation. https://ellenmacarthurfoundation.org/towards-the-circular-economy-vol-1-an-economic-and-business-rationale-for-an

[3] The butterfly diagram: visualising the circular economy, Ellen MacArthur Foundation. https://ellenmacarthurfoundation.org/circular-economy-diagram (accessed 2023-09-19)

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CE should be part of all life cycles stages of a product from production to use and end of life (which in practice should be the start of a new life). Due to the broad range, there is seldom only one measure that is needed to create a circular product, but several methods can be used. These methods can be both innovative solutions that, for example, enable recycling of the materials or minimize waste, or changes in a design that affects how a product is handled by the user so that lifespan of functionality is increased. Moreover, as depicted in the butterfly diagram above, CE principles exist both for the technical sphere (blue side) and biological sphere (green side). These two spheres will in most cases require different approaches and solutions. In the mapping made in IRISS both spheres have been considered. The technical sphere has further been divided into the subcategories set out in the so called 9R framework by Potting et al.[4] (Figure 2)

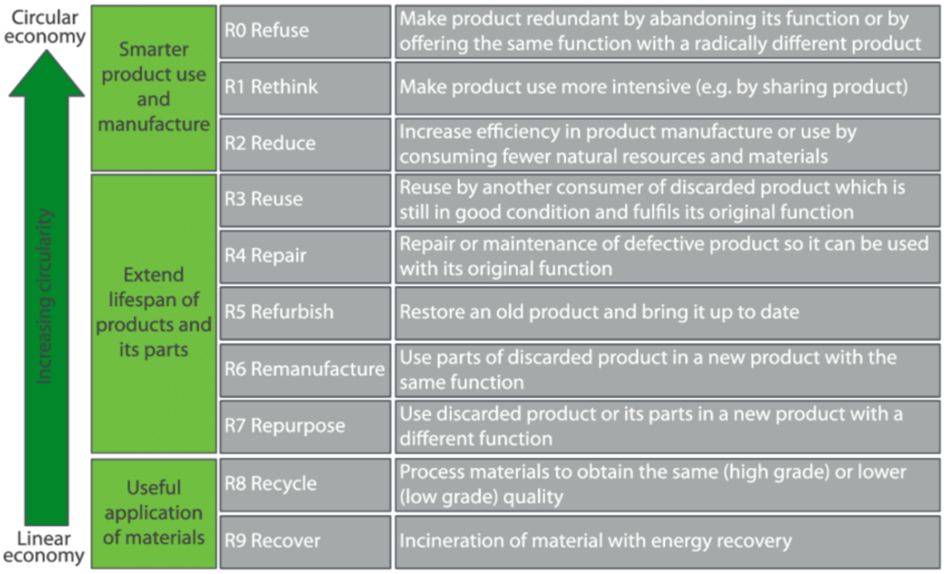

Figure 2 Overview of the 9R framework

Possible ways that CE is currently incorporated into product design, as well as potential future integration, are studied in the report. The aim is to identify criteria and methods that can be used in the SSbD framework. An analysis of both existing requirements for products (**legislation**, **standards**, **product labels**) and future requirements and possible solutions (**upcoming legislation and regulations**, **circular design guidelines**) has been made.

Legislation: The analysis of present and upcoming legislation showed that the regulatory coverage of CE principles currently is expanding, especially within various initiatives connected to the EU's Green Deal. For example, criteria valid for packaging, such as design for recycling and recyclability criteria, is about to be implemented for other sectors. The revised Ecodesign Directive, that previously mainly focused on energy related products, will in the coming years be updated to also cover almost all products entering the EU market. Digital product passport and higher Ecodesign demands is likely to be the new norm. Rules are currently being drafted in many areas, such as in the revised **construction product regulation (CPR)**, **end-of-life vehicle directive** and **packaging and packaging waste directive**. Overall, the rules connected to the technical sphere are much more common than those connected to the biological sphere.

Standardization: Along with the implementation of new legislations comes the need to update

[4] Potting, J., Hekkert, M. P., Worrell, E., & Hanemaaijer, A. (2017). Circular economy: measuring innovation in the product chain. Policy Report, PBL publication number: 2544, Planbureau voor de Leefomgeving.

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and develop new standards. Traditionally, standardization efforts have been driven by industrial needs and the development has been executed by experts from industry. However, as argued in the report, the future standardization landscape might be driven by other needs. Examples of this include regulations that aim to achieve climate related goals and those that are based on new circular business models. This changes the standardization process completely since the need then will be driven by regulatory forces, rather than by the industry.

Two interesting and important upcoming standards in the field of CE are **7.2.1 ISO/TC-207 Environmental management** and **7.2.2 ISO/TC 323 Circular economy**. They are currently being developed, and once implemented, they will be very useful for measuring and assessing the circularity of products.

Product labels: Several product labels have requirements connected to CE. As for the legislation mapping, also for the product labels there seems to be a larger focus on the aspect related to the technical sphere of circular economy. The most common requirements are connected to how the product can be recycled and reused as well as measures that increase the life span of a product. The prolonged lifetime is achieved by ensuring durable materials together with repair design embedded in the product. Also, end of life treatments to dismantle products and ensure that they can be reused are starting to appear more frequently. However, few findings were made on product control that set targets or measures for the regenerative processes such as biodegradation and conversion of biochemical feedstock.

Design guidelines for circular economy have been analyzed both on a generic level, with aspects applicable to several, preferably any, type of product and on a product specific level, with aspects targeting only one product group, for examples plastic packaging or consumable hygiene articles.

For the **generic level** it was found that regardless of product type, some design aspects are always relevant. One example of this is the need to reduce **environmental impacts over the whole life cycle** of the product (including raw material extraction and production, product manufacturing, use-phase and at end of life) and the importance of correct **material selection**. For material selection the focus is on avoiding hazardous and scarce materials and instead using low impact materials. In applications where it is suitable, the use of bio-based materials, responsible sourced materials, bio-degradable materials, and recycled material is desirable.

The **product specific guidelines** focused on the seven values chains connected to IRISS; automation, construction, electronics, energy materials, fragrances, packaging and textiles. For each value chain, a thorough literature screening of available design guidelines was made, and the results were categorized depending on their coverage of the technical sphere (9R's) and/or the biological sphere. Readers interested in a specific value chain can refer to the full report for taking part of the findings and examples. All product-specific groups shared a common characteristic: guidelines for durable and long-lived products (including reuse, remanufacturing, and repurposing) were more prevalent than those for consumables, probably due to the challenges associated with extending their lifespan.

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The information from the mapping described above was complemented with the results obtained from a **survey** performed among the members of the IRISS network and with external stakeholders. The survey was conducted online between October 2022 and March 2023 and received a total of 87 valid responses, including 37 from companies.

Most of the responding organizations, 73%, did consider circular aspects in the design and development phase (Figure 3). Looking the companies' responses, an even higher amount, 78%, answered positively. This indicates that circularity is something that is considered important.[5]

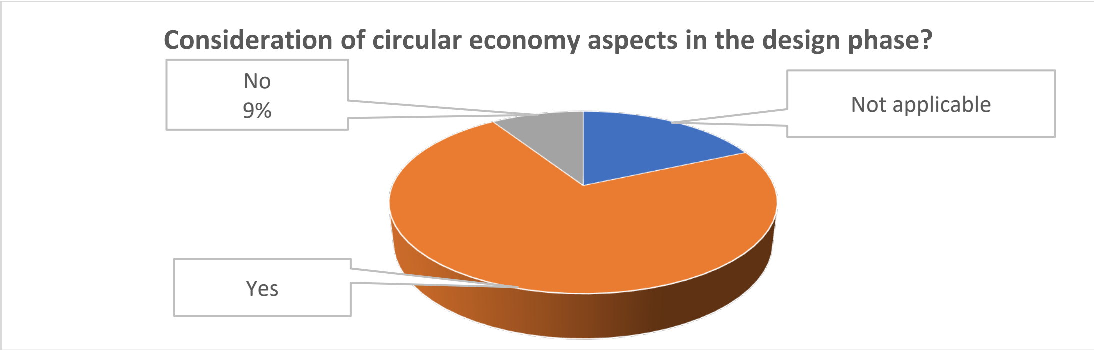

Figure 3 Circular economy aspects in the design phase.

When asked which aspects get the largest focus, respondents answered that recyclability, reduction of waste and biodegradability were the aspects most frequently considered. The fact that biodegradability was so high up in the list of considerations was somewhat surprising, given that so few observations connected to the biological sphere were found in the mapping of legislation, standards and design guidelines.

Strategies associated with "extension of the products life span", e.g., repurpose, refurbish and repair were found to be the least considered aspects in this survey.

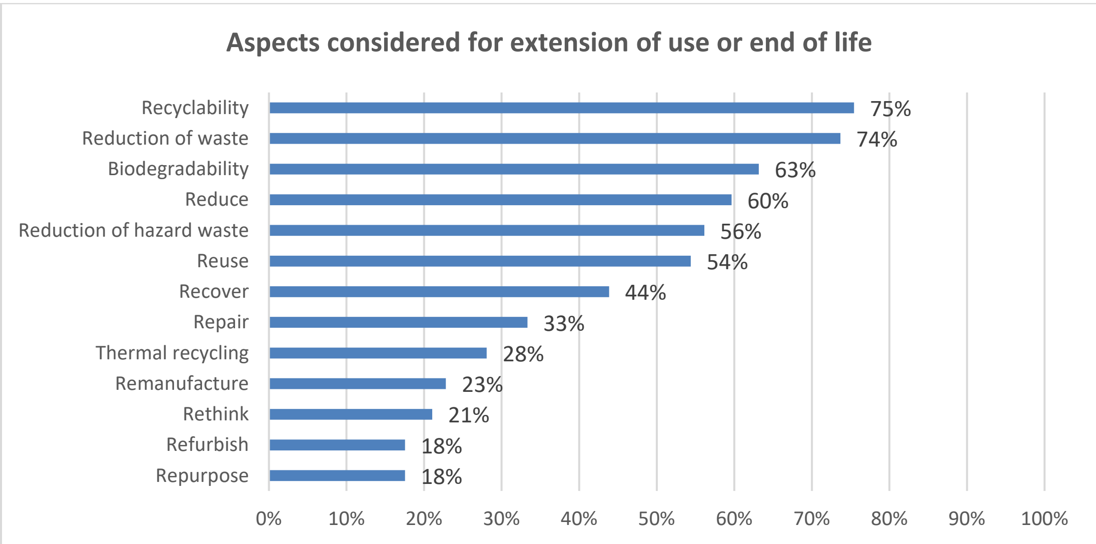

Figure 4 End of life and extension of life considerations indicated to be taken

[5] The survey may be not representative for Europe as only a few stakeholders, that already showed an interest to SSbD, answered the questionnaire. Nevertheless, the survey gives us a unique view on the many aspects and facets of SSbD, within this slightly positively biased group of interested participants.

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A **general conclusion** for design for circular solutions is that, regardless of product and value chain, the redesign of a circular solution does not only entail redesign of the product, but the **whole system surrounding the circular product**. For instance, take-back systems, maintenance/cleaning, remanufacturing facilities and processes, end of life treatment etc. Additionally, providing improved and clear information to users and various stakeholders is crucial to ensure that the product is used and handled as intended.

However, an important contradiction to consider is that a circular solution does not necessarily mean that it is a sustainable solution. For example, refusing a physical product and replacing it with a digital one may lead to increased environmental impact and resource use from a system perspective. This is because digital solutions often rely on energy and material-intensive computer systems and server infrastructure, which can have a significant impact on material availability and energy consumption. Another example can be that the energy required to return the material into the loop can exceed the profit of taking virgin material. In this case, the process, despite being circular, becomes an environmental burden.

These types of environmental trade-off exist for many solutions and to assess them, life cycle assessments are needed. LCA is part of the proposed SSbD framework, and these analyses will need to be done already at the design stage. The mapping of the LCA tools has been described in task 1.3 of IRISS work package 1.

As final remarks it can be mentioned that the existing systems towards circular economy, considering lifecycle perspective, can be used, and transformed to sharpen the requirements by using the SSbD framework. Policies can be adjusted to focus on preservation of resources, for example, instead of regulating that 85% of a car should be recycled, the focus should be on recovering 85% of all the used materials, minimizing uncirculated material. Exchange of knowledge must be enabled and encouraged. A transformation to the circular economy from the isolated stakeholders is not possible, and even competitors need to share knowledge with each other to achieve the necessary momentum.

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