Circular Design - Design for Circular Economy

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Background

Economic growth, in our linear economy, is measured by gross domestic product, in other words, the growth in throughput or the value of products and services produced. This pattern creates the consumption society, which assumes the abundance of resources and shapes behaviour around accumulation of stuff. This accumulation of stuff is manifested in three forms: non-reparability, functional obsolescence and the power of marketing. As societies attempt to mirror the lifestyles advertised in media, they fuel the unsustainable demand for new and improved products.

The linear structure design focuses on the product itself and how it is packed (Aho 2016). The cheap and available resources and a hunger to produce and sell more and more products have made manufacturers as well as consumers blind to what happens with the products after they break down or become obsolete. Sometimes, planned obsolescence has been built-in, even for products that could have lasted longer, in order to make space for brand new ones.

Traditionally design has not considered product impact during its birth and use, and what happens when it is not in use anymore and thrown away. Products were not designed to last, allowing for new models to come fulfil the needs and temptations of consumers. The emphasis was laid on product aesthetics and attractiveness, and brand promotion by applying smart marketing (Brown 2008). As a result, our consumer society has been actively seduced by new and better goods and services, leading to massive resource consumption and waste.

Pervasive seduction marketing and even cultural norms compel us to buy more and more products, which we do not really need. When the product breaks down, it is either financially not viable to repair it, or simply non-reparable. Innovation and technology development make us buy new models, as a product upgrade is almost impossible. As a result, huge quantities of goods end up in landfills, creating detrimental environmental consequences with enormous loss of materials, energy, water and labour embedded in them. As Sophie Thomas, a director of Circular Economy in RSA, stated, ‘We are convinced that waste is a design flaw’ (RSA 2014, 9).

Having more ‘sustainable’ products, partially made of recycled materials, or being more energy-efficient than their previous versions, is not enough (Hunter 2016). For instance, Bakker et al. (2014) indicate, that even though the energy consumption of studied products (laptops and refrigerators) has been reduced considerably, their life cycle has been counterbalanced and, therefore, the overall environmental impact is negative (Bakker, Wang, Huisman & Hollander 2014, 13).

Circular Design

Design in the circular economy is complex and requires a transformation in thinking, to shift 'from the current product-centric focus towards a more system-based design approach' (RSA 2014). Circular design searches for a way to deliver a product or a service, which is functional and made of optimum materials to deliver the best performance while minimizing its negative impact along the whole life cycle. (Aho 2016)

Circular design challenges a generation of products and materials in a way that minimizes the primary raw materials use. As the name implies, the focus of circular design is on curtailing a value loss embedded in these products and materials, by keeping them circulating in closed loops. These loops, such as reuse, repair, remanufacture, refurbishment or recycling, extend the product's life cycle and improve the resource productivity. At the end of the life, inspired by nature, a product, its part, or a material will become a resource within or even outside of the original application. Components could be reclaimed in remanufacturing. Materials can continue their life through recycling. The circular economy applies a combination of these strategies with a preference to the activities closer to the user or consumer, in other words, as in the inner loops of the diagram in Figure 3. (Acaroglu 2010)

The key lies in how a product or a material is designed and how different aspects and requirements are balanced. The design phase influences the product's life and the ease of its reprocessing. Designers have the opportunity to consider durability, compatibility, modularity or multi-tasking functions of designed products. However, this does not rest solely on designers shoulders (RSA 2014, 43).

Both circular design and sustainable design focus on environmental, economic and social aspects. However, how their goals are attained differ markedly. The latter puts a product, value preservation, and its eco-impact on the planet into central role. On the other hand, circular design commences with the resources' economic potential optimization through new business models. At the same time, emphasis is on resource restoration and quality of life. (Circular Product Design 2016)

New Business Models

A Products That Last project, led by the Industrial Design Engineering faculty of the Delft University of Technology, focused on discovering new business opportunities, models, and design strategies for the circular economy.

'Every new product development effort should be coupled with the development of a business model which defines its 'go to market' and 'capturing value' strategies.' (Teece 2010, 183). The Products That Last project names five business model strategies to help businesses and designers in a thinking shift towards a circular economy (Bakker & Hollander 2013; Bakker et al. 2014)

The five business models for long-lasting products are: The (1) **classic long-life model** which focuses on high-quality long life product sales, the (2) **hybrid model** combines durable products, designed to be easily disassembled, with short-life and fast-cycling, repeatedly sold consumables, the (3) **gap-exploiter model,** using the leftover value in products or components, which are still functional, broken or discarded and resells repaired or refurbished products, components or services. The (4) **access model** delivers access to a product rather than its ownership. The (5) **performance model** provides product performance rather than the product itself. Products are designed for easy maintenance, durability, and long-life. (Bakker & Hollander 2013, Bakker et al. 2014) The last two aforementioned models deliver capability and services to a user without physical ownership (Bocken et al. 2016).

Similarly, Bocken et al. (2016) discuss six potential business models for a circular economy: (1) **access and performance**; (2) **extending product value** through life extension strategies, which is similar to a gap-exploiter model; (3) **classic long life**; and an extra model, (4) **encouraging sufficiency** through principles, for instance, products' durability, upgradability, and non-consumerist approach to sales; (5) **extending resource value**, which is ,also, similar to the gap-exploiter model; and (6) **industrial symbiosis**, a process-oriented solution, which uses residual output to become a feedstock for other processes.

Strategies for Circular Product Design

Based on the Product That Last research, six strategies for Circular Product Design were identified (Figure 1), indicating an impact on product integrity. The aim of these strategies is to counter obsolescence and keep a product as close as possible to its original purpose.

1. **Design for Product Attachment and Trust**, sometimes called 'design for emotional durability' is regarded as the most challenging, aims at responding to an emotional obsolescence by creating long lasting products that people will love and trust (Bakker & Hollander 2013; Bakker et al. 2014; Circular Economy 2015; Bocken et al. 2016).

2. **Design for Product Durability** creates products resistant to wear and tear, in other words, physically durable products. Here, the material choice is crucial in overcoming functional obsolescence (Bakker & Hollander 2013; Bakker et al. 2014; Circular Economy 2015; Bocken et al. 2016).

3. **Design for Standardization & Compatibility** fights against systemic obsolescence by designing product's parts and interfaces suitable for other products and aims at multi-functionality and modularity (Bakker & Hollander 2013; Bakker et al. 2014; Circular Economy 2015; Bocken et al. 2016).

4. **Design for Ease of maintenance and Repair** counters functional obsolescence by ease of maintenance to keep a product in working condition, and non-challenging

reparability and replacement of broken parts to extend the end of the life (Bakker & Hollander 2013; Bakker et al. 2014; Circular Economy 2015; Bocken et al. 2016).

5. **Design for Upgradability & Adaptability** avoids systemic obsolescence by maintaining product usability for a long time by upgrading its value and performance, and at the same time, by adaptation and modification towards the changing needs of a user (Bakker & Hollander 2013; Bakker et al. 2014; Circular Economy 2015; Bocken et al. 2016).

6. **Design for Dis- and Reassembly** also avoids systemic obsolescence by designing products and their parts to be eventually easily separated and reassembled. This strategy has a big impact on component and material reuse and remanufacturing. (Bakker & Hollander 2013; Bakker et al. 2014; Circular Economy 2015; Bocken et al. 2016)

Figure 1: Six Design Strategies for Longer Lasting Products (Circular Economy 2015)

In addition, Bocken et al. (2016, 310) propose **Design for Reliability**, which relates to products designed with a high prospect of no failure operation throughout certain time if the manufacturer's use and maintenance instructions are observed. Also, **Design to Dematerialize,** reducing the amount of materials required but still sustaining the core functionality, should be taken into account. Dematerialization also means inventing brand new solutions with no or less material required.

Tools and Methodology for Designers

Circular economy emphasizes the importance of cooperation and collaboration across various fields; producers, suppliers, remanufacturers, logistic and recovery managers, users/consumers, academia, scholars, policy makers and researchers and developers. Especially in the design phase, the active communication between designers, material experts and engineers, environmentalists and economists, and end users is essential for an innovative circular design decisions. (Aho 2016; Medkova 2015, RSA 2014)

RSA (2013, 2014) created a tool for designers, the Circular Network (Figure 2), in which they mapped different stakeholders engaged during a product's life cycle that should be involved in the dialogue on changing design towards circularity. The Circular Network tool divides these players into segments of a circle, which emphasizes the equality and importance of all stakeholders' collective views and insights. These general segments are: consumers and users, design, academics and education, investors, policy makers, resource management, material experts, manufacturers, and finally brands and companies. The segments are then split into more detailed sub-segments. (RSA 2013, 2014)

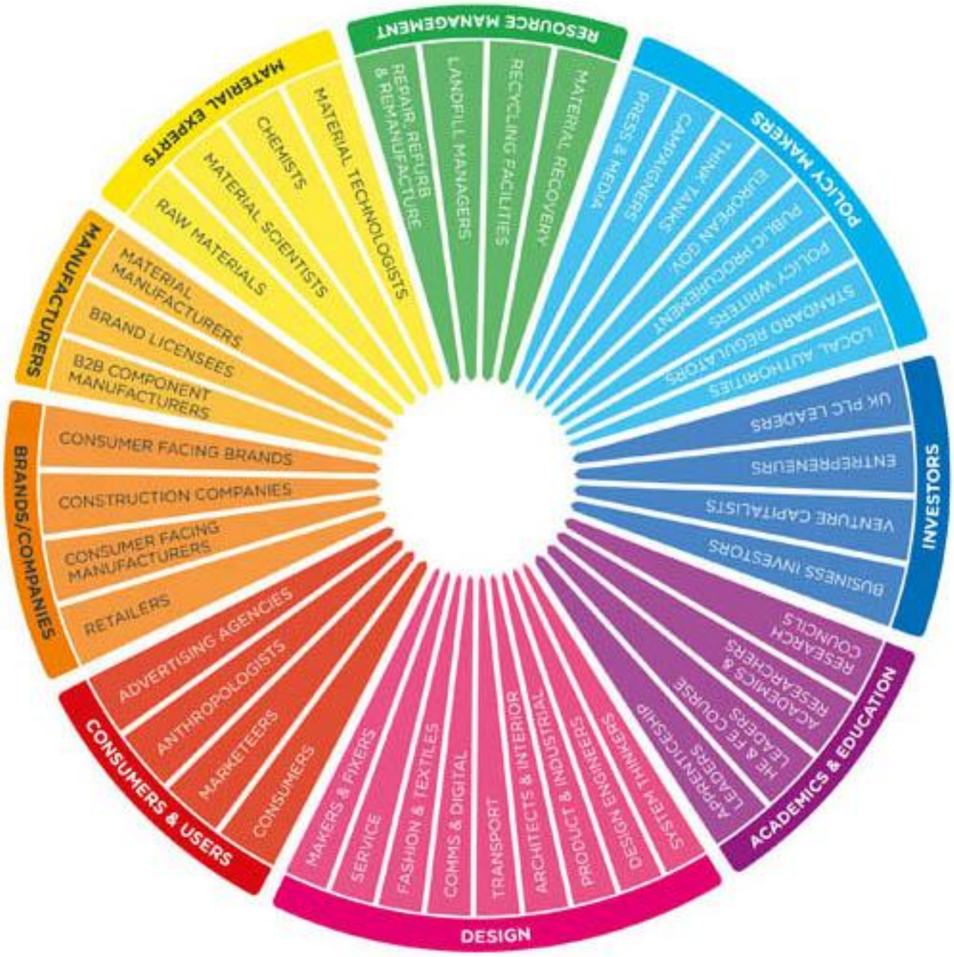

Figure 2: The Circular Network (RSA 2014)

Most of the current solutions focus predominantly on “end-of-pipe” solutions, such as recycling, which more accurately might be referred to as downcycling and major loss of embedded value. The resource challenge should not be approached from the end. Instead, we have to start at the beginning of the product, component or material life cycle, before it is physically born, during the design phase. (Medkova 2015, 68) Also, Hatcher et al. (2011) recognize that, the product’s impacts and costs during its lifespan and during reprocessing at end-of-life are determined during the design stage.
To reiterate the earlier findings ‘Product design is the starting point of the resource challenge’ (Medkova 2016, 68) for creating a sustainable and systematic approach to reconfiguring our resource dependency while supporting well-being and economic growth.

According to The Great Recovery research, conducted by the Royal Society for the Encouragement of Arts, Manufacturers and Commerce (RSA), four models can be distinguished for circular design: design for longevity, design for leasing or service, design for re-use in manufacture, and design for material recovery. The circular economy principles are expressed in the Four Design Models diagram in Figure 3, where the loops closer to the user are the most powerful. Also, the model enables designers to understand who possesses the key knowledge in all four loops (RSA 2014).

Design for Longevity promotes long life and reliable products that can be easily dismantled for upgrade or repair by the user. Security seals or glued components should be avoided in order to avoid possible warranty loss or component breakage. Open-source manuals, reasonably priced spare parts, and services should be available. This all leads to a relationship development with the user and his quality association with a product that lasts and thus brings an emotional value to the consumer to use it longer or pass it on to somebody else rather than simply dump it. (RSA 2013; Cabo 2015)

Not everything should be designed for longevity. There is a wide spectrum of products with a different length of the life cycle: short, medium and long. A very short life cycle should be predetermined for food packaging and should be biodegradable or easily recycled. A medium long life cycle can be seen in electronics which can be easily repaired and upgraded to extend the life cycle. And finally, products meant for long life cycle, such as pots and pans, furniture, jewelry should be durable not only physically but stylistically as well. (Acaroglu 2010)

Design for Leasing/Service changes the product ownership into a product as a service business model. As the product and, therefore, the material ownership stays with the producer or manufacturer, the designed products are durable and long lasting in order to maximize efficiency. The value in the product is therefore kept within the system. Product as a service can provide more users with high-tech products and higher specifications of design, which would be normally out of reach. (RSA 2013; Cabo 2015)

Another way could be selling an outcome, for instance, a ProjectBox, a package of quality professional tools, materials, and detailed instructions on how to complete a required job. Cheap, one-time used tools purchase can be avoided as well as the time and resources loss. When the job is done, the ProjectBox would be collected together with the waste and unused materials. (The Agency of Design 2016 b)
Design for Re-use in Manufacture aims at the return of old products or their components back to manufacturers for an upgrade on faulty or obsolete parts replacement, to be subsequently resold. These products are designed for longevity and easy disassembly on a manufacturing scale, in order not to waste the value embedded. The key enablers are reverse supply chain management and supporting legislation. (RSA 2013; Cabo 2015)

According to Bakker et al (2014), it is essential for designers to attain deep knowledge of 'how the product and its parts wear and tear, and of how to decide which parts should last, and which should be replaced, and when' if the product is expected to be refurbished several times during its life cycle. Many aspects ought to be considered, the functionality, appearance, and costs. (Bakker, Wang, Huisman & Hollander 2014)

Easy non-destructive and quick disassembly can be attained, for instance, by placing a small pellet next to a snap-fit joint. Using a vacuum, the pellets expand and open the snap fits and, thus disassembly of a product with high-quality material reprocessing and recovery is possible. (The Agency of Design 2016a)

Despite the significant economic, environmental and employment benefits, remanufacturing continues to be undervalued and under-recognised, reveals the recent Remanufacturing Market Study (2015) sponsored under Horizon 2020. In Europe, knowledge transfer across industrial sectors is missing, both for remanufacturing and recycling (Remanufacturing Market Study 2015, 10).

Design for Material Recovery recaptures materials and products to be reprocessed and recycled into new materials. This involves components that cannot be repaired or upgraded but also fast-flowing products and materials such as packaging.
Using single rather than complex materials and avoiding toxic materials increases recyclability. Also, developing accreditation systems for secondary materials will boost the designers, manufacturers and consumers confidence. (RSA 2013; Cabo 2015)

The below-mentioned tool (Figure 3) serves only as a guideline for designers, as no one-fits-all solution for designing circular products exists. Different life extension and repurposing strategies are needed for different product characteristics, such as resource intensity, life expectancy or technological and style maturity, and business limitations, such as legislation or market dynamics (Bakker, Wang, Huisman & Hollander 2014).

Figure 3: The Four Design Models (The Great Recovery 2013)

Various methods, indicators, and tools can guide the designers or companies in their decisions. So far, these measurements have indicated only specific business drivers or were designed for linear operations. Based on the Ellen MacArthur Foundation (EMF), Circularity Indicators Project (2015), no circular economy metrics exist. (Circularity Indicators 2015a, 2015b, 2016) A complex methodology providing the systems thinking still needs to be developed.

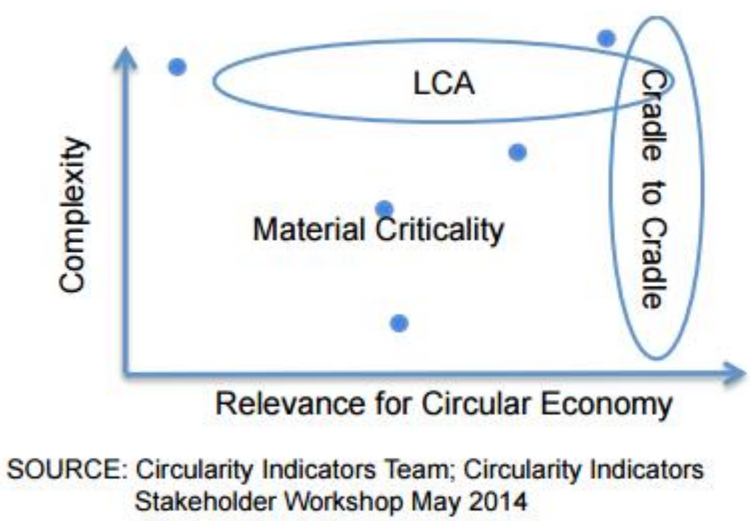

Figure 4: Stakeholder Perception of Existing Indicators (Circularity Indicators 2016, 7)

Life Cycle Assessment (LCA) and Cradle to Cradle (C2C) only partly indicate circularity and exclude material criticality as seen in Figure 4. LCA tool evaluates environmental aspects and impacts of a product or a service during its entire life cycle. C2C is a framework of biological and technical nutrient cycling and which aims at eco-effective waste-free production.

In 2015, Circularity Indicators (CI) methodology and a web-based tool were developed by EMF together with Granta Design and co-funded by the European Union to measure a company's 'linear to circular' transition progress. The CI tool deals just with technical cycles and non-renewable materials. The focus is on products or companies' material flow restoration level. Circular Indicators are particularly intended for product designers to guide their decision making and can serve internal and external company reporting, procurement and investment purposes as well. (Circularity Indicators 2015a, 2015b)

Circular Indicators consist of the main Material Circularity Indicator (MCI) and optional complementary indicators for additional insights: complementary risk indicators (material price variation, material supply chain risks, material scarcity and toxicity) and complementary impact indicators (energy usage, economic benefits, or CO_2 emissions). The results obtained from the MCI range between zero and one; low values show linear flows and the maximum value of one represents fully circular flow. (Circularity Indicators 2015a, 2015b) The LCA and MCI could be combined as many of their input data are identical (Circularity Indicators 2015b, 11).

The success of the circular design or circular economy in general, depends on transforming the whole system and redesigning our thinking and ultimately, the collecting and return systems. The same importance should be paid to the infrastructure establishment of various rejuvenating processes (repair, rebuild, recycle, etc.), and the information and knowledge exchange via active dialogue between various stakeholders to spark innovation. By creating ongoing and circulating material and information flows, a product, a component or a material will get to the right and most value saving player in the system at the time, in order to extend product life or give it a second or multiple life cycles. Changes in technology, products and markets are dynamic, so should be the circular design strategies, policies, and processes (Bakker, Wang, Huisman & Hollander 2014).

Education

The shift towards a circular economy is associated with a change in our attitudes, mindsets, perceptions and behaviour. It requires the change in a way of thinking and acting, going towards sharing and collaborating. Educational institutions are responsible for implementing circular economy principles into their curricula and developing the required new skills and competencies. Based on the RSA (2014) study, an action-based learning is recommended, including teardown workshops and various supply chain site visits (RSA 2014, 41).

Cross-disciplinary education can be beneficial as it encourages and impacts people to see world views from a different angle. At the same time, it helps people understand complexity and systems thinking. (Martin et al. 2007) Multi-disciplinary education not only broadens designers' knowledge of other fields, it also offers them an opportunity to practice communication and problem-solving strategies with non-design students. This will be essential when dealing with colleagues and clients from different backgrounds in the future. (Design Council 2010)

New competencies, knowledge and working methods for core areas of functional circular design need to be developed. According to the EMF, these areas include: 'material selection, standardized components, designed-to-last products, design for easy end-of-life sorting, separation or reuse of products and materials, and design-for-manufacturing criteria that take into account possible useful applications of by-products and wastes'. (Ellen MacArthur Foundation 2015)

Circular Economy Design Concept

Based on the literature research, a Circular Economy Design Concept is depicted in Figure 5. The circular economy design is the engine of the circular economy. The vehicle for changes is Redesign. Redesign occurs by focusing on the four lines of discussions (Systems Thinking, Awareness, Mental Shift, and Communication) around the four elements (Circular Design Strategies, New Business Models, Cross-disciplinary Intelligence, and System Conditions).

The three dimensions of People, Planet, Profit both drive and are driven by circular design and influence the redesign processes in the circular economy. In Figure 5, the overall mutual impact of a circular economy design on three dimensions: People, Planet and Profit is emphasized by the bidirectional drivers. Also, these three dimensions are symbiotic, because changing one dimension has a direct impact on the other two dimensions. Not only does the circular design have an impact on the social, environmental and economic aspects of the circular economy, but People, Planet and Profit influences the design at the same time. Continuous redesigning enhances the understanding and appreciation of the four elements.

The first (1) element, Circular Design Strategies, consists of various life-extension strategies. It aims at designing long-lasting and durable products that are easily maintained and repairable, upgradable on a modular basis, and standardized. It ensures easy dis- and reassembly, and product structure adaptability.

New Business Models (2) are closely bound to Circular Design Strategies. These models focus on long lasting products offered as services, sharing platforms, and enabling a product access or performance, rather than its ownership. As the main producers' and manufacturers' focus is not anymore on volume, additional revenues are generated from additional services offered along the entire product life cycle to counteract the drops. The aim of the new business models is to retain products, components, or materials of the highest utility and value. It includes easy maintenance, cost-effective repair, refurbishment, and remanufacturing. Additionally, resell and remarketing of used products are included, as the first user is not meant to be the last one. The re-commerce and value recapturing activities require a functional take-back system and reverse logistics. The supply chain is not anymore one-way only, but it includes both directions: to the market and from the market.

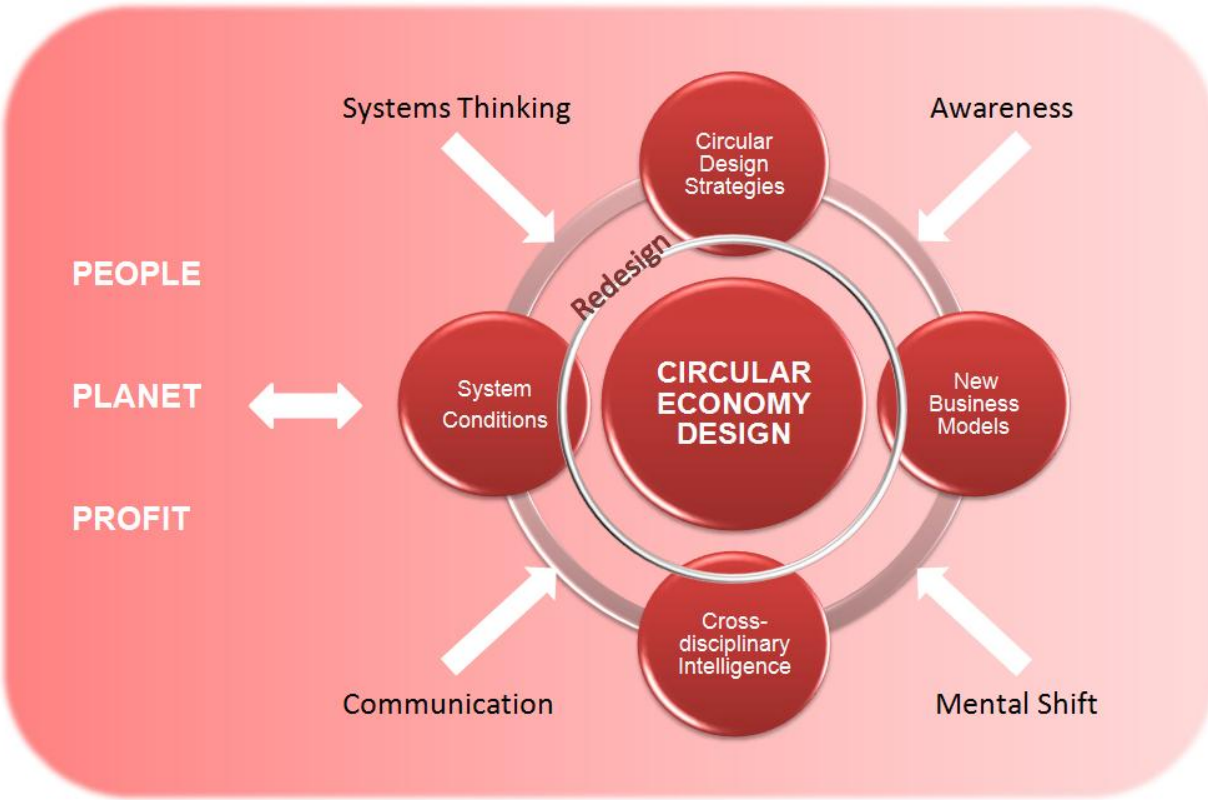

Figure 5. Circular Economy Design Concept

Systems Thinking is vital for the circular economy concept. As Joël de Rosnay (1979) proposed, the world should not be looked at through a microscope, to see all the details, nor through a telescope, to see the distance, but through a new tool, a macroscope. The macroscope is a symbolic tool made of various methods and techniques that diminishes details but observes the big picture and magnifies what links things together. 'The roles are reversed: it is no longer the biologist who observes a living cell through a microscope; it is the cell itself that observes in the macroscope the organism that shelters it.'. (Rosnay 1979) In order to think in systems, Cross-disciplinary Intelligence (3) is necessary. As the name implies, the intelligence comes from various sectors, industries, and players, and can be obtained through cooperation, collaboration and new partnerships. Furthermore, it involves mapping and evaluation of various aspects: social, environmental, economical, cultural, emotional, physical, and technological. Looking at the systems holistically is a prerequisite for a functional circular design and economy.

The fourth element, System Conditions (4), empowers the circular economy supportive environment. Just to name a few, sector-specific legislation, incentives, mandatory and voluntary programs, financial instruments to spur technological innovation and R&D, functional infrastructure, and information and material flows are encouraging for the adoption of circular business models. Policy measures can raise consumers' and producers' awareness about circular economy practices and products and advocate for the importance of repairability and durability. Developing corresponding assessment tools and methods, and quality standards help the transition towards a circular economy. Moreover, new skills and expertise are needed for these new ways of thinking, working, valuing, and new lifestyles. As the circular economy is a dynamic and developing concept, circular design reflects this evolution by continuous redesigning and system innovation. For that, a constructive debate amongst relevant stakeholders and information sharing must be facilitated. Also, the circular economy drivers, reasons, benefits, and challenges need to be communicated, in order to raise the awareness and importance of this topic. Only then, mental shift and an attitude change can take place.

Conclusions

Design for a circular economy combines leveraging of the main four elements (Circular Design Strategies, New Business Models, Cross-disciplinary Intelligence, and System Conditions) with the four lines of discussion. By focusing on redesigning processes, the lines of discussion reflect the reprioritization of our choices. Circular design thinking is not a marketing buzzword. Circular design takes into consideration People, Planet and Profit, and is embedded as a core strategy for businesses and consumers.

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