MOVECO

CIRCULAR ECONOMY INNOVATION TOOLS

Principles of Circular Economy

Qualification Programme Handbook

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2. INTRODUCTION

2.1. INDICATIVE GUIDELINES

This document can either be used as background material for trainers and participants in a workshop or also by individual readers (self-study or within a self-formed study-group). For both cases, there are notes provided that guide through the material

For the practical work, there are several exercise and a case study that invite discussions or reflections. In the end, there is a short quiz to test the knowledge gained in this section of the toolbox. You will find any specific terminology explained in the glossary. If you use this section as part of a workshop, there is an evaluation form at the very end that can be used to collect feedback at the end of the workshop.

3. PRINCIPLES OF CIRCULAR ECONOMY

3.1. BACKGROUND

The concept of circular economy (CE) gains more and more interest in the European Union countries, UK, China, and Japan due to the steadily increase of material use at the global level and due to CE potential at economic level. The United Nation Environment Programme (UNEP) shows that over 80 billion tonnes of material is extracted annually, and the growing in world population will push material extraction to over 180 billion tonnes per year by 2050. This illustrates a critical situation on a planet with limited natural resources. Scarcity of natural raw material increases the cost of extraction and exponentially influences natural environment in a negative way. Intensive agriculture also degrades the land at a high rate. About 25% of the agricultural land is highly degraded or degrading quickly. Considering the influence of the global climate change, too, additional challenges will occur in the future in terms of land availability for agriculture. Under these circumstances, the paradigm of circular economy is not any more an academic subject. It must be urgently adopted by industry and specific regulations to encourage the related economic model must be adopted by politicians at national levels and in international treaties. Circular economy paradigm is illustrated in Figure 1.

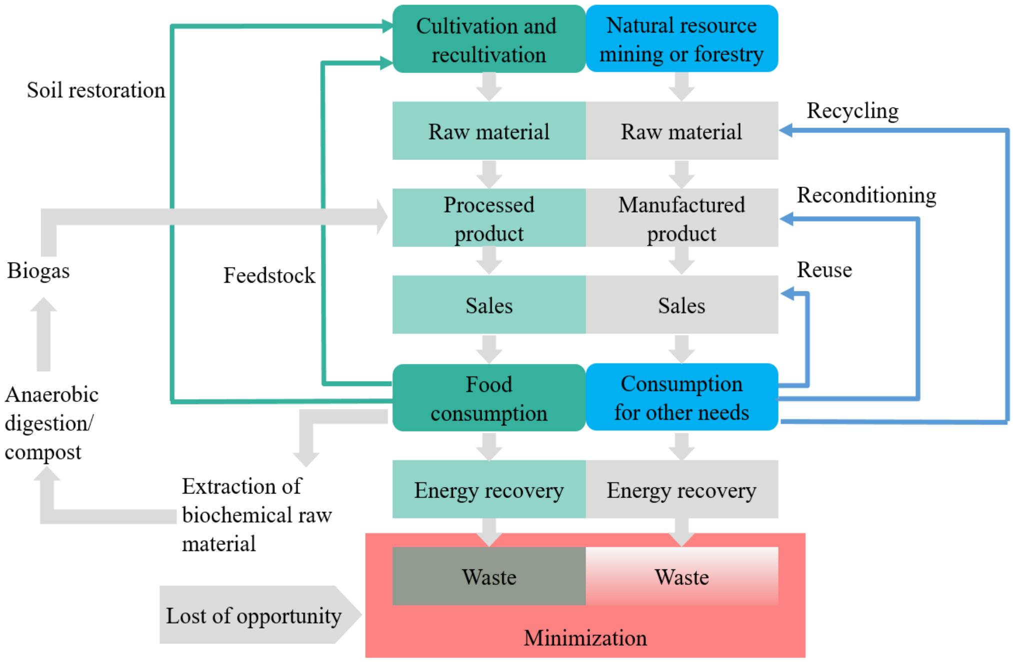


Figure 1. The two major streams of circular economy: technical and agricultural loops

As Figure 1 shows, circular economy is about recovering resources at their highest quality from consumed products and transforming them into new raw materials or new parts to be reused, thus keeping them in circulation for several life-cycles into new products, for future consumptions. As Figure 1 highlights, circular systems are either technical or biological. Both encapsulate a range of activities that reduce the demand for material inputs and recover/reuse materials already in the system.

For example, in a technical cycle, a machine-tool can be first repaired, then constitutive parts are refurbished and reused; and finally, those components that cannot be used are transformed into raw materials by melting and recovered (e.g. in the form of raw bar alloys) for manufacturing new parts. This flow extracts the highest quality and value at each stage in the product life-cycle. Circular biological systems focus on bio-waste, such as agricultural and food waste, where opportunities exist for chemical production (e.g. biofuels and fertilisers) and energy generation. Thus, in the model of circular economy, waste is dramatically reduced in comparison with linear economy, and components and materials have higher value. This model leads to new economic and employment opportunities, while providing environmental benefits through improved materials and energy use.

However, to enable circular economy, we need an adequate design of products and novel business models that keep to producers the ownership on the manufactured products over their entire life-cycle. McKinsey & Co estimates a worth of 1.8 trillion € by 2030 if implementing CE paradigm in Europe. By reducing the total material requirement of the EU economy by 17-24 % we could create 1.4 to 2.8 million jobs in new economic activities, and a reduction with 2-4% of total annual greenhouse gas emissions. Value added activities and new economic businesses in relation with circular economy are illustrated in Figure 2.

Circular economy is not an option to linear economy; it is the forthcoming model that will rule businesses. Economies will need to be more resilient; therefore, new regulations that will extracharge energy, pollution and materials rather than workforce will come in place. New business models such as total cost of ownership, product-service systems and servitization will count more and more because they encapsulate the concept of circular economy; thus, ensuring economic growth within the limits of ecological sustainability and decoupling business growth from resource use and environmental impact.

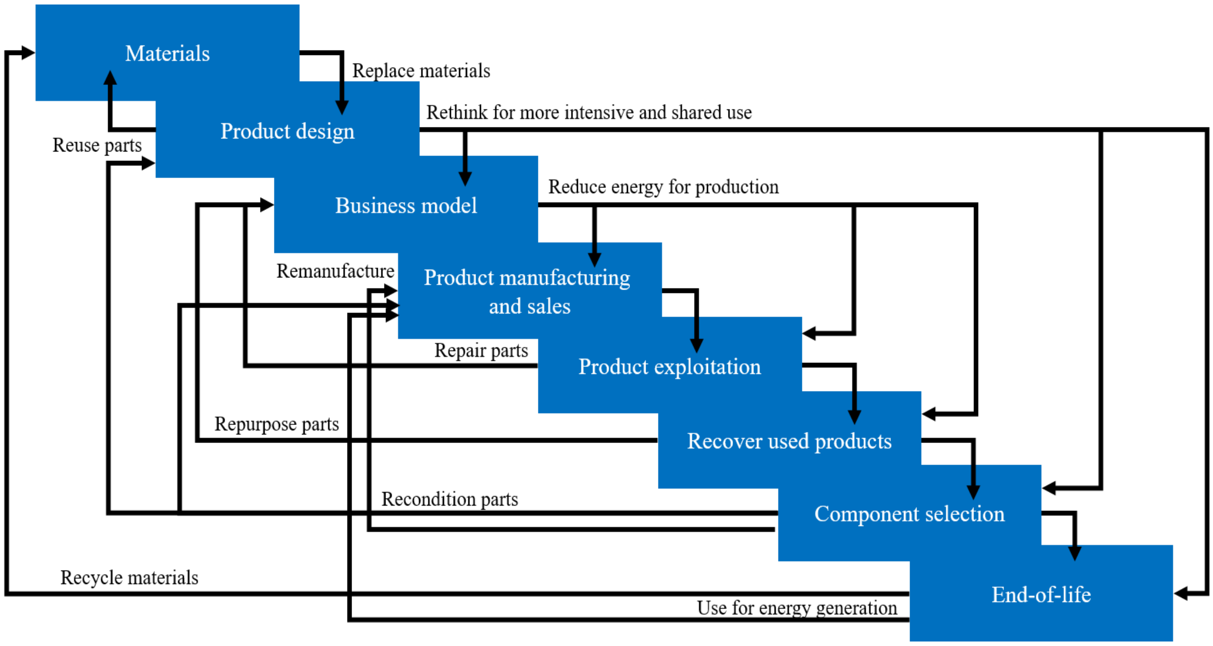


Figure 2. Value added activities in circular economy of technical products

To master the complex ecosystem that sustains circular economy, it is essential to innovate in every stage of the chain visualized in Figure 2. Circular economy, as any other potential economic model, cannot be implemented without ensuring a financial sustainability of all businesses in the value chain. Therefore, circular economy comes in package with innovations in product design, business models, product manufacturing, product operation and servicing, product withdrawal, and product "reincarnation" into new products. Figure 3 highlights the financial awareness in mastering circular economy.

Understanding the costs over the whole life-cycle of a product is essential to implement circular economy concept to the level of each link along the value chain of the business. In this respect, it is important to base every activity on solid design and management principles. They are further introduced. Principles are grouped into two categories, according to their promoters.

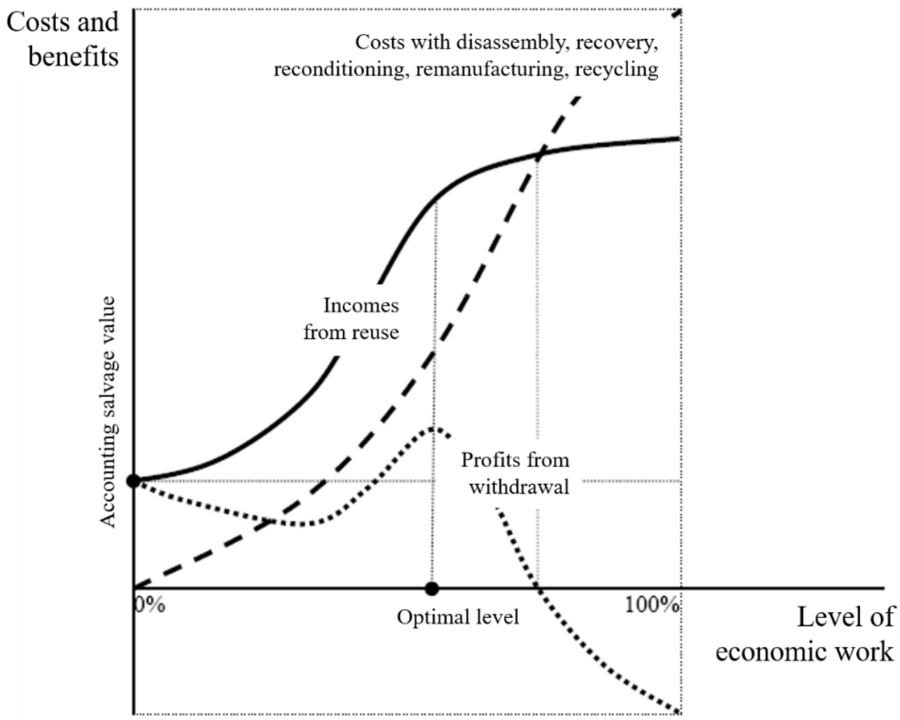


Figure 3. Mastering circular economy from a financially sustainable perspective

3.2. PRINCIPLES OF CIRCULAR ECONOMY ACCORDING TO BS 8001:2017

The British Standard 8001, released in 2017, introduces six key principles of circular economy. They are as follow:

1. System thinking: understand how your business impacts the whole ecosystem
2. Innovation: manage resources for more value creation
3. Stewardship: take responsibility for the ripple-effect impacts that come up from your business activities
4. Collaboration: secure benefits at system wide level by strong cooperation in the value chain
5. Value optimization: keep materials at the highest value and function quality
6. Transparency: reveal to everyone the environmental impact of all your business activities

System thinking principle

According to this principle, companies must consider a holistic approach in product design and manufacturing to understand how individual decisions and activities affect the wider ecosystem, including natural environment, social and economic dimensions. A system is a group of interconnected elements within their own environment. Elements interact each other according to some rules to achieve an overall objective. Systems perform functions that are connected to bigger systems. If an element is removed from the system or its dynamics is changed, the system is disrupted, unbalanced and operates differently (e.g. with malfunctions). In business, the term "systems thinking" refers to a management and operations approach where single business decisions are analysed based on the systematic consequences they have. If a company invests in a new manufacturing line (e.g. robotization), for instance, systems thinking leads to an analysis of the additional infrastructure, employee hiring and training, business delay costs that would result, as well as to energy consumption, productivity, servicing of technology, withdrawal, etc.

In the context of BS 8001:2017, system thinking is about understanding the complex, nonlinear, and interconnected perspective of a system (e.g. a product, a business, a chain of interrelated businesses, suppliers, etc.). Any part of a system (e.g. people, organizations, regulations, etc.) generates attractors (e.g. feedback loops, constrains, relationships, etc.) upon some other parts of the system. It is important to understand all these relationships such as to design company's activities in order to maximize value added in terms of intelligent and sustainable management of resources in the portfolio of solutions (e.g. services, products, product-service systems) delivered onto the market.

In order to better understand this principle, it will be shortly exemplified on a car designed for urban areas. Today we are aware that driving automobiles contribute to pollution and greenhouse gases released into our atmosphere. What can we do about this issue? Many people look to buy more efficient cars to reduce their impact on the environment. However, these cars (including the electrical ones) are still designed with the same basic thinking as all others from the market.

Thus, the goal for urban mobility would be: design a mobility unit that is as energy efficient as possible for meeting basic everyday needs of personal transportation. In whole system thinking, the aim is not to design a better product as compared to what already exists, but to look at the problem being solved and design a better solution to that. As a consequence, in this particular case, the goal from a system thinking perspective would be to build a << cheap, safe, and quick method of personal transportation that could rely only on the amount of energy that could be collected from home >>.

Putting the problem in this way, the design requirements are dramatically reconsidered. They would look as follow:

- Use the least amount of energy possible for every km travelled
- Generate minimum possible pollution during manufacturing, exploitation and recycling of the car
- Consider materials that are available in the geographical proximity of the place where the car is built and used
- Consider only materials that can be recycled several times
- Consider only materials that last long time
- Conceptualize a design that is simple, easy to build and easy to maintain and repair
- Conceptualize a design that ensures highest safety for driving
- Respect standards and regulations applicable to any regular car
- Conceptualize a solution that can be cost-effectively manufactured even in small quantities
- Conceptualize a solution that can be also mass-producible
- Be cost affordable
- Be with a nice look, etc.

With these requirements on the paper, designers will focus during the engineering design phase to minimize the weight of the car and to minimize its aerodynamic drag without affecting aesthetics, to eliminate any feature that is not necessary such as to make the car simple and affordable (e.g. three wheels: one in front and two in the back), to design a modular concept, to use special composite materials from polymers with biodegradable self-reinforced properties (e.g. polylactic acid fibre (PLA), polyhydroxybutyrate (PHB) that originally were targeted for food packaging industry, glass fibre, and other resins derived from biomass), to use two smaller electric motors instead of a larger one in order to increase flexibility in placing parts in the given volume, etc.

Innovation principle

According to this principle, companies must innovate in a way that creates business value through the sustainable management of resources incorporated within products and services they design. In other words, this principle strives for connecting economic and environmental gains in product design, manufacturing and use. BS 8001:2017 looks at innovation as everything that generates a new output and/or outcome which realizes or redistributes value. Circularity requires a radical review and reconsideration of consumption and production, with significant implications on current practices and methods of doing business.

The key question in circularity-driven innovation is: “How to extract value from what otherwise is seen as waste?” More than this, innovation principle is looking for business models where companies sell solutions not products, and owning is replaced by sharing. Innovation is looking along many vectors, such as safe and cost-effective materials that harness the Sun’s energy to clean up air and water, low-cost technology to capture CO_2 and transform it into useful chemicals. Biotechnology can open new frontiers for synthetic bacteria that eat plastics, as well as enzymes and proteins that are capable to produce renewable materials from plant fibres. In industrial processes, companies can invent partnerships to share some production facilities, such as equipments, water, energy, and to manage together the waste. CO_2 reduction from industrial processes, as well as CO_2 capturing and eventually valorisation in creating new materials is a constant innovation objective in circular economy.

Using waste as secondary raw materials to complement primary raw materials is another line of innovation in circular economy. Development of closed-loop manufacturing systems is of big importance to put circular economy into practice. This requires waste collection, selection, generation of new feedstock or chemicals or raw materials, nut also ways to recycle unwanted materials. Application ranges from mechanical components, to electronics and textiles. Treatment of heavily polluted water is another link in the chain of circular economy, especially in the case of metal and plastic processing industry, but also in the chemical and food industry.

Beyond generation of very pure water, innovations have to recover valuable minerals, metals, and other constituents that can be returned into new production cycles. Preoccupations in circular economy is also in the field of bioeconomy. Minimization of waste in fishery and development of smart ways to avoid unwanted catches is one of the possible examples in circular bioeconomy. In manufacturing, innovation principle of circular economy considers both the concept of multiple product life-cycle and the concept of 6R-closed loop system (recover-recycle-redesign-reduce-remanufacture-reuse), as it is shown in Figure 4.

To put innovation principle into practice, companies in any field of activity and in any position in the value chain have to apply design for X methodologies and methods. X generically describes a target function. In real life, circular economy indicates that a product, process or technology has to be simultaneously designed with respect to several target functions. For example, a car engine shall be designed such as to be light, with high power, fabricated from recyclable materials, to involve low costs to be manufactured, to be reliable, to have low consumption, be easy to maintain, and compatible with bio-fuels. One can see that some target functions are in conflict with other target functions. Besides this, every target function comprises a list of specific requirements. Many of these requirements are coupled. Thus, complexity of design is quite high. This challenge cannot be solved without application of optimization tools and systematic problem-solving methods.

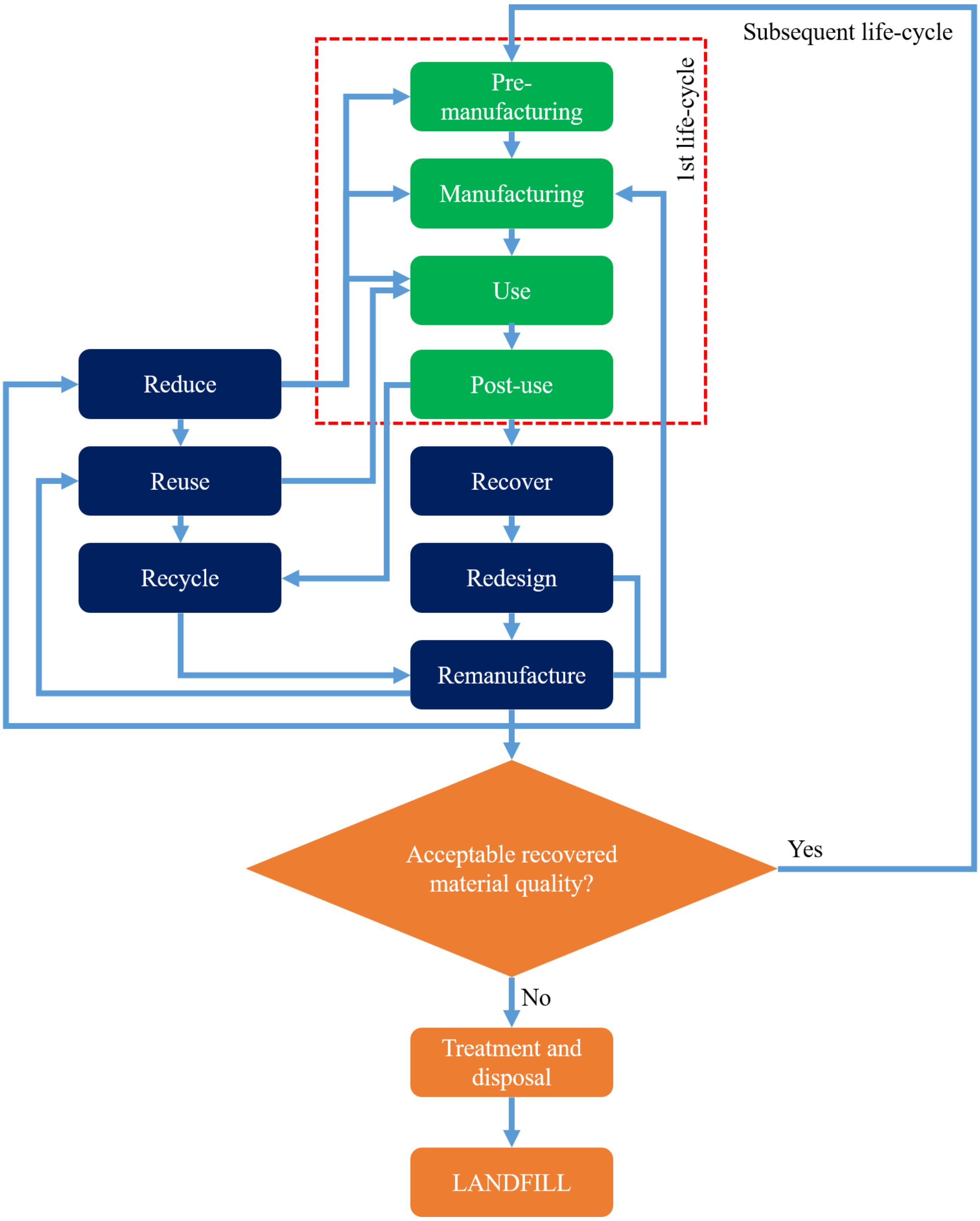


Figure 4. 6R-based closed loop in sustainable manufacturing

Stewardship principle

According to this principle, companies have to manage the direct and indirect impacts of their decisions and activities across the systems they create and interact with. In the context of BS 8001:2017, stewardships means a company is responsible for any consequence of its managerial decisions in relation to product design, its production and exploitation, as well as its end-of-life. The term "product stewardship" is a bit confusing, but as a starting point it may be interlinked with the concept of "extended producer responsibility" (EPR). Product stewardship evolved along time from responsible management of hazardous wastes towards a wider focus on resource conservation. In essence, the objective of stewardship principle is to minimize the environmental impact of products through the multiple life-cycles. In this respect, besides the preoccupation to optimise the design of products such as to reduce their environmental footprint during manufacturing and exploitation, stewardship is about defining clear processes to recover products at the end of their life from the users and prepare them for after life. This involves cost-effective disassembly, sorting, preparation for recycling of some parts, preparation for reconditioning, refurbishing and reuse of some other parts, and eco-preparation for disposal in the landfill of some remaining parts. To recover products at the end of their life, companies develop various agreements, some being fully regulated, some others co-regulated and some other being fully voluntary. To increase effectiveness of stewardship, official regulations at national and international levels seem to be the most effective means from a practical consideration.

For example, the ELV Directive adopted by EC in 2000 regulates now the automotive industry to dismantle and recycle cars in an environmental friendly way. Considering that a car has in average 10,000 components, and its life-time is about 10-12 years, material selection becomes a very challenging task in the perspective of reuse or recycling. Therefore, many metallic parts have been replaced with plastic components in the car structure. To clarify the practical implementation of ELV directive, several car manufacturers jointed their efforts to develop a software platform to assist them for part dismantling (IDIS: Internal Dismantling Information System). A key feature of IDIS is the identification of economically recyclable plastic parts. All parts exceeding 100 grams are coded to ensure systematic "closed-loop-recycling", some materials going back into new cars as secondary raw materials. With IDIS, car manufacturers prevent the use of hazardous materials, ensure information for consumers and increase the motivation to integrate recycled materials in design.

In ship industry, disposal of hazardous waste is regulated since 1989 under the Basel Convention, with additional issues under the Hong Kong Convention in 2009. As a consequence, over 95% of the ship components (e.g. those made from steel, cooper, and aluminium) are reused or recycled. In aircraft industry things are only at the pilot phase, showing that about 85% of an airplane's body can be dismantled and the resulted parts to be reused or recycled. The use of Enterprise Information System (EIS) and Product Life-Cycle Management Systems (PLM) is essential to support product stewardship. In synthesis, as BS 8001:2017 highlights, stewardship principle is about accountability of any action undertaken by organizations and its employees. Thus, in product development, companies should consider impacts on society and environment from upstream processes (e.g. what materials are used, from where they will be purchased, how production is run) and downstream processes (e.g. delivery, installation, use, servicing, and end-of-life).

In the current paradigm of consumption-driven economy and excessive profit-oriented mindset of doing businesses, it is a big challenge to motivate companies to turn into the closed-loop paradigm of circular economy without strong policies and regulations (e.g. extra-taxation of materials, energy, transportation, under-taxation of workforce). Nevertheless, it is also possible to run smart businesses, with very good profits, by adopting circular economy principles, despite the existence or not of regulations in this respect. Managers should be inspired in this respect by complementary concepts to circular economy, such as creating shared value, lean production, product-service systems and servitization, leasing, by-products, sharing economy, total cost of ownership, resilience, etc.

Product perspective and related business models are those that enhance the capacity to implement circular economy. Nevertheless, governments are even more responsible, through their attitudes and facts, to encourage this behaviour. For example, some states in EU are lagging behind with respecting common regulations about waste selection, recycling and deposition, paying from public money huge amounts of penalties.

Collaboration principle

According to this principle, companies have to conduct continuous cooperation, both internally and with external stakeholders, through various business arrangements such as to create mutual business value for all stakeholders. Cooperation in circular value chains is dictated by the complexity of these chains and the related business models. As BS 8001:2017 highlights, it is a less probability that an individual organization could be capable to tackle circularity in doing businesses and to support transition towards a more eco- and social responsible business models without cooperation. In circular economy, life-cycle orientation, responsibility and/or ownership are key characteristics of the business models. This means, in circular economy, we discuss about system-scale innovation; that is, individual companies depend on the maturity of suppliers in emergent value chains.

For example, a company that intends to use recycled plastics as raw materials cannot implement this strategy if, in the value chain, there are no networks which collect and sort plastic residuals, others that process residual plastics into raw materials, and others that store and supply these raw materials. And all these economic activities should reach a critical scale to be also productive and financially sustainable. But when an innovation is introduced in a business model (as the case of circular economy) there are many gaps and dysfunctionalities in the associated value chain; and this aspect is even more critical when the value chain has an international or global dimension.

Thus, activation and synchronization of economic activities in circular value chains require coordination, cooperation and strategic partnerships, including the intervention with regulations of central authorities. Recovery of removed products, transportation and reprocessing require dedicated economic chains and production facilities. Conversion of a production process to a one that is capable to work with recycled materials involves adaptation costs, too. For example, to repurpose an existing installation of steel manufacturing into an installation that deals with high quality recycled steel would involve tens of millions of € (short-term adaptation costs).

Also, even if from a demolished construction we can recover about 86% of the waste, its value is highly diminished because of mismatching between supply and demand, transportation costs, storing costs, as well as because of the challenges related to multi-material sorting. Standardization in every sector that could implement circular economy is also necessary. Standardization of materials used in different products would simplify the recovery and recycling processes. This requires to share data between stakeholders in the circular value chain. In order to avoid commercial sensitivity that makes companies hesitant to disclose data and information, neutral bodies must be established to deal with these data. Creation of cooperation, reflection, sharing and learning spaces is an important issue, but this can be facilitated by cluster initiatives on circular economy. In this respect, efforts must be channelled along at least three vectors of evolution.

The first vector, which requires extended cooperation, is related to the suitability and innovation of materials. The second vector is about establishing value chain networks, and the third vector is related to progressive leadership and collaboration. Thus, we have to ensure that selected materials are suitable for loop closure. The quality value and purity of scrap materials must be protected from contamination with lower value materials, otherwise the commercial proposition is compromised. A sustainable value chain avoids down-cycling, meaning that reused or recycled components into a new product are not of lesser quality or lower value added. Creation of novel eco-friendly materials and use of such materials in designing new products is also necessary. Traditional transaction-based supply chains have to be replaced with value chains where every stakeholder is responsible for ecological and social value creation, but also to enhance cooperation in extended business systems, such as to understand how interfaces between businesses can be improved. It is already proved (see the theory of reasonable optimum of the Nobel Prize winner John Nash) that only cooperation can move business potential beyond the traditional limits, in places where the product of utilities is maximized.

Material, financial, commercial and contractual issues must be well understood and detailed such as to deliver winning business cases in circular economy. To keep every player from the value chain motivated and engaged, communication between partners and trust building are crucial factors. To make this thing happens, specific triggers must be in place, such as strategic alliances and joint venture models. In a circular economy, all parties have to engage in shared value models and broader project scopes and objectives, beyond individual interest. This sounds unrealistic for many people with an egocentric mindset. But there are champions able to demonstrate success stories as sources of inspiration for the majority. As any system-scale innovation, implementation of circular economy will take time, unless the case of sufficient political will to apply the new paradigm globally. Functional cluster initiatives are very good means to provide early momentum in this demarche.

Value optimization principle

According to this principle, companies have to keep all products, components and materials at their highest value and utility at all times, such as recirculation to be done with minimal energy consumption. Recirculation, in any form, is not the goal of circular economy. Recirculation is only a mean to create new value in the system from elements that are considered loss or waste. Value added is in cost saving, in lower environmental impact, in higher business resilience, in new revenue streams and in better relationships with customers. Optimization is reached when the normalized impact (value weight) of each business activity in the value chain and each component from the product is of the same magnitude with their normalized costs. Thus, according to circular economy, the goal is not to optimize profit but rather the value.

Value optimization moves even forward, looking not only for preservation of natural capital, optimization of resource yields, and fostering of system effectiveness, but also for social dimensions in order to remove poverty by involving, as much as possible, disadvantaged social categories into high value added economic activities. Optimization of value creation through circularity is illustrated in Figure 5.

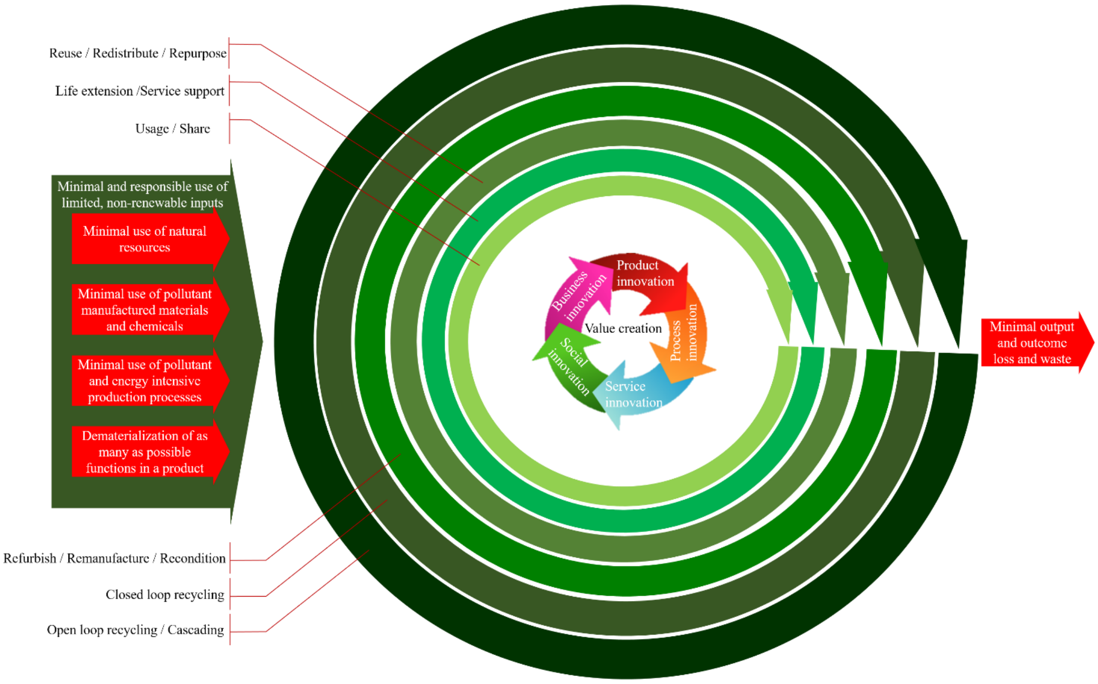


Figure 5. The mechanism for optimizing value creation in a circular economy

According to Figure 5, optimization of value is about finding an alternative (a solution) with the highest possible performance under given constrains (e.g. human, financial, natural, technological), by maximizing useful and desirable factors while minimizing harmful factors. Priorities will follow the rule: natural capital first, followed by human capital and then by manufactured capital. As Figure 5 shows, materials that are seen as waste in production or post-consumption can become valuable resource inputs in new products and applications. In this case, optimization is about minimizing the waste generation and maximizing the reuse of the resulted waste. Moreover, value can be increased by using products longer (prolonging their life-time) or recirculating them in multiple cycles (e.g. second hand refurbished industrial robots) with minimal modifications.

This approach requires cooperation across the value chain to enable changes in the design of products and the development of reverse logistics and reconditioning processes. New types of business models such as leasing or servitization can enable all stakeholders (producers, intermediaries, end-users) to capture a share of value. In addition, Figure 5 indicates a new value stream that can be optimized, specifically the spare capacity. There are spaces and equipments that are heavily underutilized by a single organization, indicating low returns on investment. By smart partnerships, such capital can be better exploited, sometimes with a neutral management of a third party. Sharing of facilities can be considered in all dimensions: business-to-business (B2B), business-to-customer (B2C), and customer-to-customer (C2C). Value optimization principle is also about many interlinked outcomes. For example, the output of reducing CO_2 emissions generates, as a first layer outcome, improvement of air quality. A better air quality leads to an improved natural environment and better health of population. This reduces costs with health systems and environmental interventions; thus, public money can be redirected to other areas, such as education and social security. In fact, reduction of CO_2 emissions is an important aspect that encourages adoption of circular economy at large scale.

At the current rate of economic growth, by 2100 world economy will be 80 times larger than today. In the last 25 years, world economy was doubled, but the Earth ecosystem was degraded with over 60%. CO_2 emissions were with 40% more in 2015 than in 1990, even if the technological progress has led to reduction of CO_2 emissions from 1kg/$ economic activity to 770 grams/$ economic activity. To have a decent living of the 9 billion people of the planet, world economy should grow of 15 times by 2050 and of 40 times by 2100. If all 9 billion people would aspire to a living standard comparable with that in advanced countries, technological innovations should lead to a reduction of CO_2 emissions of about 11% every year to stabilize the climate on Earth, meaning 16 times faster than was happening from 1990 until now. Until 2050, CO_2 emissions should be of 6 grams/$ economic activity; that is, 130 times less than today. Stabilizing CO_2 at 550 ppm means that minimum 2% of the world GDP to be allocated in reducing CO_2 emissions (the limit is however 450 ppm; that is, an absolute reduction of CO_2 emissions with 50-85% by 2050). Besides the outcome of improved air quality, we have to consider several other outcomes that encourage application of circular economy. They are: abundant energy, improved human development, valued manpower, valued human role, improved life, improved health, regenerated lands, and better valorisation of used resources, as well as decoupled nutrients from industrial and agricultural activities.

Transparency principle

According to this principle, companies are fully aware and open about decisions and activities that affect their ability to move towards a more sustainable and circular mode of operation and are willing to communicate their effects in a clear, accurate, timely, honest and complete manner. In this respect, companies have to work in a systematic way to ensure traceability of materials they use, where they come from and who made them. Moreover, responsibility covers impact of their work on environment. In this line, companies have to conduct researches to understand the effect of materials and processes they use to the level of natural environment. In addition, they have to communicate how materials release certain compounds in the air, soil and/or water and whether they cause any negative effects.

In parallel, companies have to put in place processes and measures that contribute to the annihilation or reduction of the harmful effects on natural environment. This requires facts that prove preoccupation and action to use the best possible materials after a comparison of several options. Cost-benefit analyses from an economic perspective (not only from a financial one) have to be also performed such as to demonstrate the usefulness of materials in relation with the doubt concerning their use. This principle is also important in relation with EU policy of increasing up to 70% the recycling target by 2030. The principle of transparency is also about accepting the fact that waste companies see in the linear economy is not any more waste, but rather the fact that everything has a value. The incapacity of people to maximize the use of natural resources and materials, of products and assets makes waste to be seen as waste. Thus, companies are responsible to identify how the intrinsic value of what we call now "rubbish" can be valorised and transformed into economic value. In fact, waste valorisation into new products is a 4.5 trillion € business opportunity.

3.3. PRINCIPLES OF CIRCULAR ECONOMY ACCORDING TO "ELLEN MACARTHUR" FOUNDATION

According to "Ellen MacArthur" Foundation, circular economy is "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 and aims for the elimination of waste through the superior design of materials, products, systems and business models". From this definition, "Ellen MacArthur" Foundation promotes a "butterfly" diagram to visualize circular economy, with three layers conducted by three major principles, as it is shown in Figure 6.

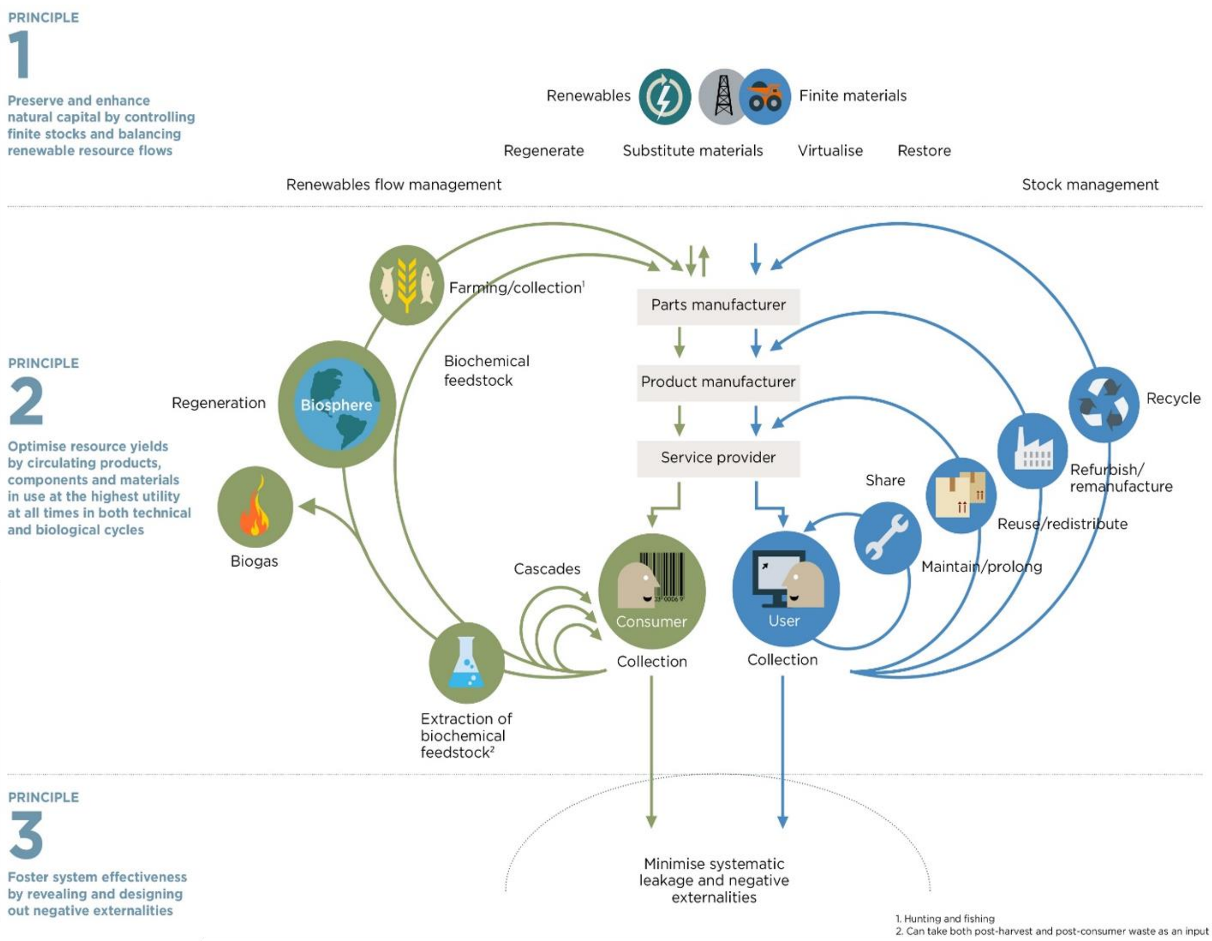


Figure 6. Principles of circular economy within the flow of material transformation over the life-cycle (source of picture: website of "Ellen MacArthur" Foundation)

- Principle of preserving and enhancing natural capital by controlling finite stocks and balancing renewable resource flows
- Principle of optimising resource yields by circulating products, components, and materials in use at the highest utility at all time in both technical and biological cycles
- Principle of fostering system effectiveness by revealing and designing out negative externalities

Analysing the three principles promoted by "Ellen MacArthur" Foundation, we can see that all of them are actually captured in the value optimization principle of BS 8001:2017. The three principles highlight the need to integrate natural environment as a key "stakeholder" in the economic model. This paradigm penalizes the Keynesian economic model, indicating that consumption must be only in the limits of our capacity to regenerate the raw material ecosystem and life ecosystem.

Preserving and enhancing natural capital principle

The term "capital" describes a stock of anything that has the capacity to generate a flow that benefits and is valued by people. The emergence of the concept of natural capital indicates that environmental systems play a key role in the economic output and human well-being by providing resources and absorbing emissions and wastes. Natural capital is the most fundamental form of capital since it provides the ground conditions for human existence. These conditions include fertile soil, multifunctional forests, productive land and seas, good quality freshwater and clean air.

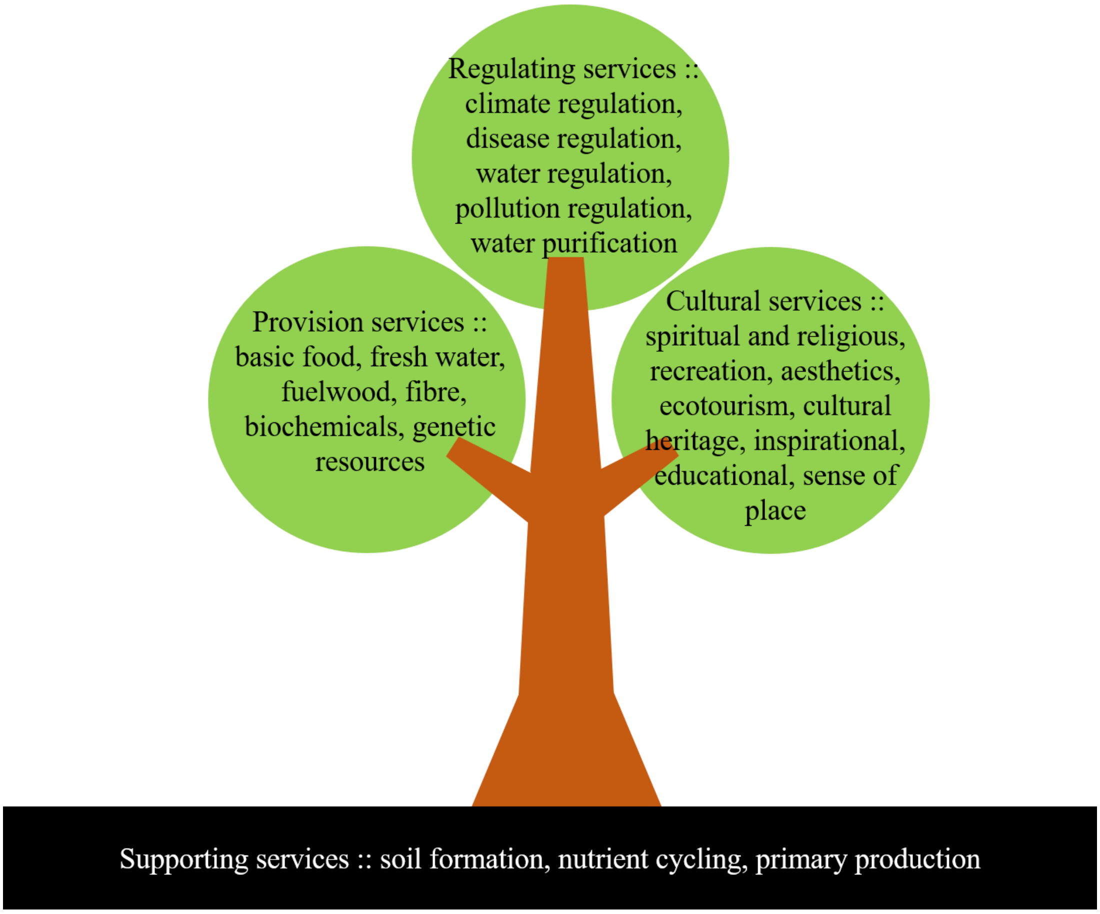


Figure 7. Natural ecosystems services

They also include critical mechanisms such as pollination, climate regulation and protection from natural disasters. Natural capital sets the ecological limits for our socio-economic systems. The complexity of natural systems and irreversibility of some transformations in nature indicate that replacing natural capital with other forms of capital is non-substitutable and involves catastrophic risks. This is the reason we need to integrate natural capital in our economic and social systems. Because individuals usually behave irresponsible, politicians are mainly in charge to state and implement very severe regulations that will turn our behaviour from consumerism and profits to resilient economic models. It is important to emphasise that natural capital is not the same as nature; natural capital is the basis of production in the human economy and provider of some processes through natural mechanisms (e.g. pollination). The key question with respect to preservation and enhancement of natural capital is: Who is paying for the services provided by natural capital? In this respect, Figure 7 illustrates, in a synthetic way, these services.

Optimising resource yields principle

The second principle promoted by "Ellen MacArthur" Foundation indicates practices to design physical products for easy remanufacturing, easy and cost-effective refurbishing, and cost-effective recycling to keep technical elements and semi-fabricated materials in circulation for several life-cycles; thus, contributing to natural capital preservation and reduction of natural ecosystems degradation.

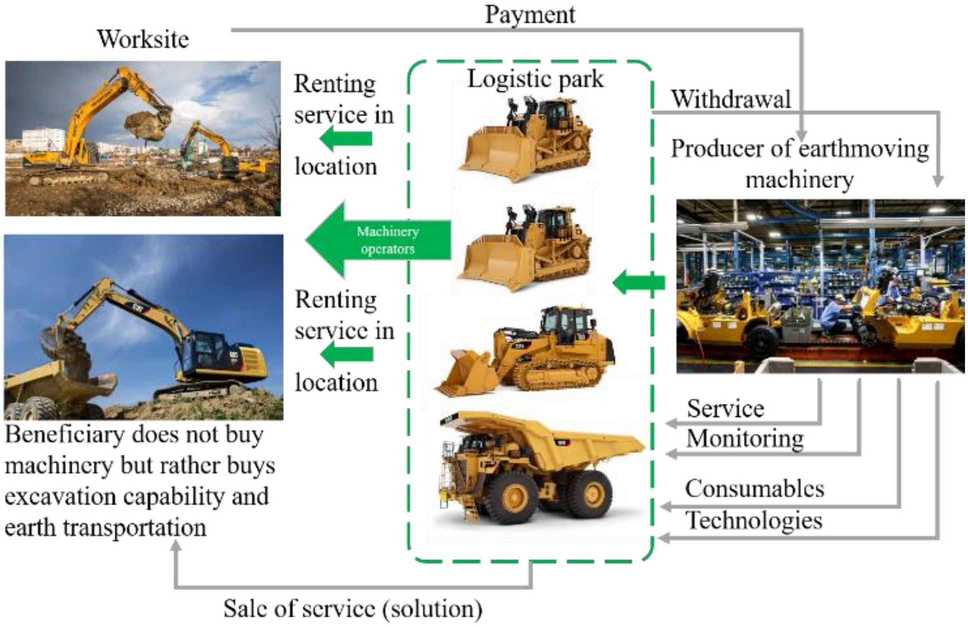


Figure 8. Example of product servitization in earthmoving industry

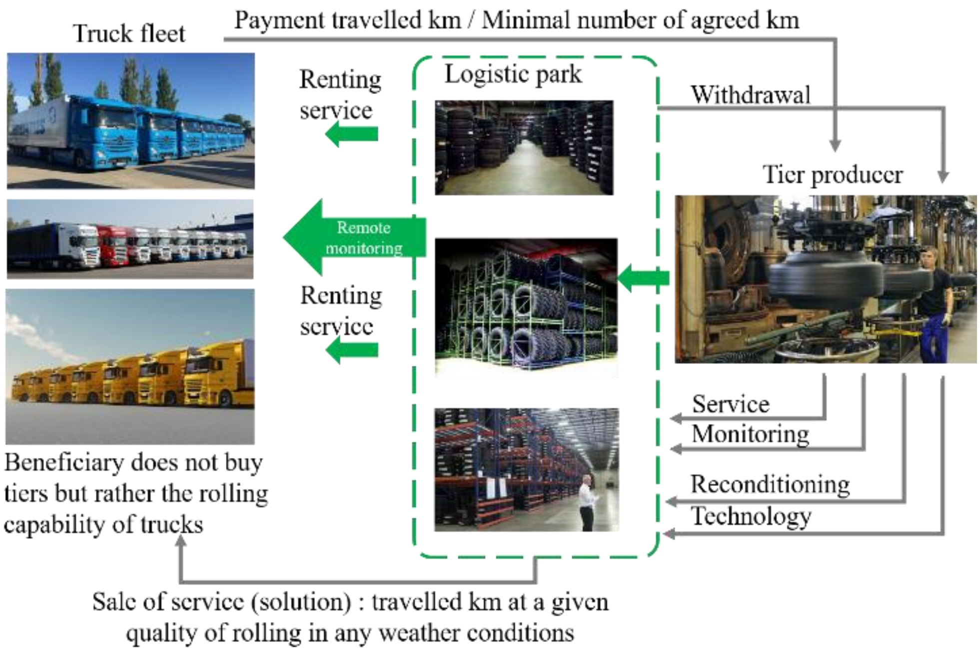


Figure 9. Example of product servitization in consumable industry

According to the second principle, instead of waiting for recycling parts at the end of their life-time, it is more responsible to intervene with tighter, inner loops (e.g. maintenance, upgrading) during the usage period to prolong useful life of products and components. Thus, revenue streams must be generated not from encouraging consumption, but from encouraging upgrading of current products and replacing current business models (based on commercial transactions between producers and consumers) with leasing, renting and servitization models. Two examples of product servitization are shown in Figure 8 and Figure 9.

Minimization of negative externalities principle

In line with the third principle, negative externalities are referring to costs that are suffered by third parties as a result of economic transactions. In a transaction, producer and buyer are the first and second parties, whereas the third parties include individuals, entities and resources that are indirectly affected in a negative way. Negative externalities are also referring to external costs. Some negative externalities, such as waste, arise from consumption, while other negative externalities, such as CO_2 emissions, arise from production of goods and products, from energy production and from transportation of goods and people. Negative externalities occur in those situations where property rights over assets or resources have not been allocated, or are fuzzy. Who owns oceans, water from rivers and lakes, nutrients from soil and air from atmosphere? Where there is no private property on these resources or the state is a poor manager of natural resources, first and second parties may pollute them without fear of being called to court. A negative externality, such as the cost of pollution from industrial production, makes the curve of marginal social cost higher than the curve of private marginal cost. This is suggestively shown in Figure 10.

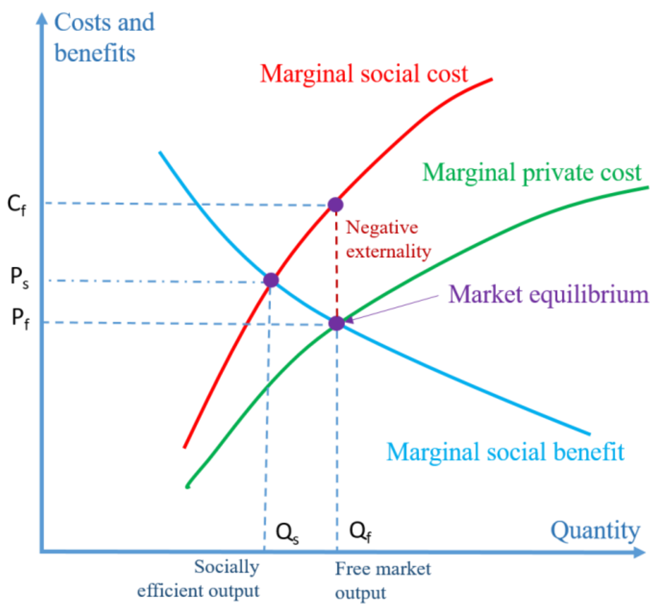


Figure 10. Negative externality due to lack of social property rights on natural resources

As Figure 10 illustrates, if spillovers are introduced in the equation of business, beneficiary must pay the price P_s for the output Q_s. Because there is no advocate of environment and society to protect them against harmful effects (e.g. air pollution, soil degradation, water pollution, food chemicalization, etc.), market equilibrium is set at Q_f for the price P_f, with $Q_f > Q_s$ and $P_f < P_s$. On short term, beneficiary is happy because it buys cheaper, and producer is happy because it produces more. But there is a cost of this game, equals with $C_f - P_f$, which actually means loss of welfare. Over-production is thus welfare loss. In conclusion, we need a third party in the game, which must be responsible to negotiate the price with the first and second parties such as to reduce negative externalities. The equilibrium is when the price is P_s and the produced output is Q_s. Thus, governments MUST INTERVENE on our behalf through taxes, direct controls and regulations to make consumption more responsible and to force producers to innovate such as to obtain sustainable profits at the price P_f for the quantity Q_s, and the difference $P_s - P_f$ to be used by governments for preservation and enhancement of natural capital. Examples of government interventions are taxes for CO_2 emissions done by cars, airplanes, ships and industrial processes. Negative externalities from production include air pollution from factories, industrial waste, noise pollution from transportation, methane emissions from zootechnical processes, pollution from agricultural fertilizers, collapsing of fish stocks. Negative externalities from consumption include household waste, toxic particles from vehicle circulation, air pollution from smokers, noise pollution by individual activities, litter from tourism, spillovers generated by unhealthy food and drugs, traffic congestions, etc.

3.4. CONCLUSIONS

Circular economy is about introducing social costs in the economic equation and, as a consequence, identification and application of efficient and effective tools and approaches in product design, production, usage and withdrawal by respecting a set of well-defined principles that finally lead to a responsible consumption and production for more resilient social and environmental ecosystems at global scale. Even if proper regulations and control mechanisms can reduce negative externalities, companies can innovate on products, processes and business models by themselves using the circular economy paradigm and generate new revenue streams. Limitations are not in technology, but rather in the indolence and lack of understanding of decision makers. Application of circular economy principles is feasible and can lead to profitable business activities. Climate change, natural resource scarcity and political interests to relocate economic activities will accelerate the adoption of circular economy paradigm. Those companies that will act proactively to adopt the principles of circular economy in their activities will attain competitive advantages. This message is addressed to any type of company, either it is an original equipment manufacturer or a simple supplier of components, as well as to famers and food producers.

3.5. EXERCISES AND CASE STUDY

Exercise 1

Describe the value chain of your organization and indicate where and which principles of circular economy are already implemented, and how they are implemented. Where you identify gaps, indicate which principles of circular economy can be introduced and how. Use the canvas from Table 1 to perform this exercise.

Table 1. Canvas for value chain analysis against circular economy principles

Support processes	Principle (what)									How the marked principles are implemented	Indicate principles that might be added	Indicate improvements to current state (what and how)
	System thinking	Innovation	Stewardship	Collaboration	Value optimization	Transparency	Natural capital preservation	Optimization of resource yields	Reduction of negative externalities			
Firm infrastructure												
HR management												
Technology development												
Procurement												
Primary processes	Principle (what)									How the marked principles are implemented	Indicate principles that might be added	Indicate improvements to current state (what and how)
	System thinking	Innovation	Stewardship	Collaboration	Value optimization	Transparency	Natural capital preservation	Optimization of resource yields	Reduction of negative externalities			
Inbound logistics												
Operations and production												
Outbound logistics												
Marketing and sales												
After-sale services												

Exercise 2

In Table 2 you will find an example (an electric car) that shows how different outputs and outcomes are interlinked in relation with circular economy. Elaborate this exercise for the case of a product or service executed by your organization. Consider the ten target outcomes from Table 2, but indicate the related outputs and intermediary outcomes in your case. Here, output refers to a result and outcome refers to the effect and impact of the output at a larger scale and over a longer time (e.g. years or more).

Table 2. Canvas to analyse outputs and outcomes of products in relation with circular economy

1. Target outcome: improved life of people Intermediary outcome: zero driving noise and increased passenger comfort Output: manufacturing energy consumption Output: engine concept and design; car concept and design	**5. Target outcome: valued human role** Intermediary outcome: developed new service businesses Output: extensive experience of passengers	**7. Target outcome: sufficient energy** Intermediary outcome: developed new service businesses for charging batteries Intermediary outcome: developed new service businesses for recycling batteries Intermediary outcome: land pollution end-of-life of batteries Output: limited energy storage Output: batteries concept; batteries composition
2. Target outcome: improved health of people Intermediary outcome: zero driving CO_2 emissions Output: manufacturing CO_2 emissions Output: engine concept		**8. Target outcome: improved human development** Intermediary outcome: safer driving Output: better ratio cost-benefit Output: driving system
3. Target outcome: decoupled bio-nutrients Intermediary outcome: developed new businesses in the value chain Output: cascading usage		**9. Target outcome: decoupled tech-components** Intermediary outcome: recycled batteries Intermediary outcome: customized services Output: reusable parts Output: buy-back of parts Output: economies of scale Output: mass market
4. Target outcome: regenerated land Intermediary outcome: developed solar plants Output: eco-footprint Output: land degradation by mining Output: new resources needed	**6. Target outcome: used resources** Intermediary outcome: developed new businesses and services in the value chain Output: multiple waste streams Output: smarter design and design for life-cycle	**10. Target outcome: valued manpower** Intermediary outcome: ensured linear employment Output: replace workers with roots for repetitive activities

Exercise 3

Identify and estimate the negative externalities in the case of products or services provided by your organization. An inspirational example is given below, with the request to continue completion of information in Table 3.

Table 3. Partial example of negative externalities and measures towards circular economy

Company X : producer of cell-phones	**Product** : smart phone model Y
Negative externality	**Measures to compensate**
Hinders grammar of users	Education in schools can make young people conscious about negative implications of the improper use of phones for text messaging.
Reduces face-to-face communication	In restaurants or bars people started to introduce the rule "who plays more with the phone will pay the bill of consumption". Restaurants can exploit this rule by introducing devices that count the minutes every customer used the phone.
Increases incidents of car accidents	Over 30% car crashes involved cell-phones. Need to introduce laws that prohibit drivers from text messaging and from cell-phone use. Very high fines for breaching these laws.
Creates addiction for unnecessary activities	Calculate the average number of hours per day you play on the smart phone. Count how much you earn per hour and you can estimate the cost of your addiction.
Attack to privacy because of unauthorized audio and video records and dissemination on social networks	Private discussion and activities are recorded without the consent of the recorded person(s) and then uploaded on various platforms (e.g. Facebook, Twitter, YouTube, etc.). Need to introduce laws that prohibit unauthorized records. Very high fines for breaching these laws.
Creates illnesses to human body due to phone's antenna	Frequent and intense use of cell phones can generate various health problems due to the RF signals from the phone's antenna. These problems include brain cancerous tumours such as gliomas, non-cancerous tumours of the brain such as meningioma, non-cancerous tumours of the nerve connecting the brain to the ear, non-cancerous tumours of the salivary glands.
Pollutes environment with toxic compounds from discarded cell batteries	Please fill in this box.
Pollutes air with RF waves that affects birds	Please fill in this box.
Creates illnesses to human body due to the networks of antennas for signal transmission	Please fill in this box.
Pollutes environment due to the production of cell batteries (see compounds such as lithium, cobalt, nickel, aluminium, titan, manganese, plus sulphurs in some cases)	Please fill in this box.
Pollutes environment due to the production of electronics from the phone	Please fill in this box.

Company X : producer of cell-phones	**Product** : smart phone model Y
Pollutes environment due to the production of plastic components of the phone and accessories	Please fill in this box.
Destroys land due to the excavation and mining to extract Be, Mg, Ti, V, Mn, Fe, Co, Ni, Cu, Zn, As, Nb, Ag, Sn, Sb, Ba, Ta, W, Au and Pb; rare earths, which are not easy to mine, and are also met in cell phone's composition (about few grams) are: neodymium for the magnets in headphones, but also gold, palladium, platinum	Please fill in this box.
Pollutes environment to process excavated material to obtain semi-finished materials	Please fill in this box.
Pollutes environment by airplanes to transport electronic components in the global value chains and finished products to the final users	Please fill in this box.
Destroys forests due to the use of cardboard packaging for final products	Please fill in this box.

Exercise 2.4

Assess maturity of circularity concept in your organization using the checklist below (Table 4). Propose measures of improvement.

Table 4. Canvas to assess maturity of organization against circular economy principles

	Not approached	Starting	Growing	Maturing	Refining
System thinking	No evidence of system thinking ❒	Some techniques* of system thinking are applied in some projects ❒	There is a vision for circular economy activity and some activities constantly reflect resource management in relation with the value chain and wider system ❒	System thinking techniques are widely used to analyse and design any activity in organization and causality linkages and feedback loops are functional to properly progress vision, strategy and objectives related to circular economy ❒	It is demonstrated that system thinking is routinely applied in organization at all levels, optimization at product and process level is clearly demonstrated with respect to circular economy principles and staff is well trained in practical tools for circular economy ❒
Innovation	Innovation is sporadic based on reaction to opportunities, not proactive ❒	Some principles of circular economy are seen in the linkages with customers and future business strategy ❒	Top-level management is committed to innovation driven by circular economy principles and these innovations visibly integrate all stakeholders in the value chain with tight loops ❒	There are structures and staff in the organization that are responsible to continuously improve circular economy practices in all key activities, impact is constantly monitored and all social costs due to negative externalities are	It is demonstrated a sustainable management of resources and creation of business value through adequate product and service innovation, organization being involved in business model innovation for creating new value

	Not approached	Starting	Growing	Maturing	Refining
				supported by organization ❒	streams towards circular economy ❒
Stewardship	No focus on recycling and disposal ❒	Knowledge about the direct and indirect impact of environment generated by organization are administrated and efforts to improve resource management are demonstrated ❒	Decisions take into account environmental and social risks and opportunities, and preoccupations to improve resource management are clearly identified, but little issues beyond the direct control of organization are undertaken ❒	Environmental and social risks and opportunities are well defined and understood across the whole value chain and resource management fully considers these issues; in addition, some indirect issues are also managed ❒	It is demonstrated that direct and indirect impact of company's activities across the value chain is managed with responsibility and effective actions are undertaken to tackle risks and harmful effects ❒
Collaboration	Collaboration is limited to transactions with suppliers and distributors ❒	Some considerations are in place that show how organization can collaborate with other parties to explore in partnership models of circular economy; most of these actions are limited to suppliers and customers ❒	There are in place all elements for a functional collaborative approach to support circular economy but its application is only partial both in the organization and in relation with stakeholders in the value chain ❒	Collaboration with stakeholders towards circular economy is functional and the related processes can be easily identified and known ❒	Collaboration to enhance application of circular economy paradigm is happening with all stakeholders ❒
Value optimization	Focus is on financial indicators and no preoccupation on life-cycle management and servitisation models ❒	Some considerations are given to the management of resources in relation with products and services, with a special focus on value related to the end of life and reduction of waste and harmful effects of the disposed waste in nature ❒	Value optimization is recognized by employees, with clear processes in place for most of the phases (design, production, end-of-life) ❒	There are implemented effective tools to optimize value, including those activities done with other parties, and resource management is seen from a systemic perspective ❒	It can be demonstrated that products, materials and components are kept at their highest value and utility in all phases of their life-time and negative externalities are minimized ❒
Transparency	Resources and not managed based on IT systems and information about resource management are poor disseminated internally and externally ❒	Information about the management of key resources related to aspects of their value is understood and basic information about recyclability of some materials delivered to customers can be provided on request ❒	Transparency in relation with circular economy is accepted by the top management and systems to manage this issue are prepared, but most of the actions are rather passive or reactive than proactive ❒	Visibility of information about resources and their impacts is actively planned and there are effective processes in place to offer such information to any third party, including partners and clients, about the circular economy activities ❒	Solutions are in place to deliver complete information about resource value from all upstream partners and to provide proper advices to all downstream partners to maximize the value of resources at the end of their use ❒

• *Examples of techniques used in system thinking: 18 words, affinity diagram, conceptual model, context diagram, decision matrix, functional FMEA, ARIZ, sigma-TRIZ, function means analysis, functional analysis, IDEF, functional modelling, graphical analysis, influence diagram, input-output diagram, matrix diagram, morphological box, multiple cause diagram, N2 analysis, six steps system thinking, quad of aims, rich picture, root definition, sequence diagram, spray diagram, systems map, tree diagram, mind-mapping, fishbone diagram, FAST diagram, FBD, push-pull diagram, causal loop diagram, structure-behaviour pair, computer modelling, behaviour over time diagram, system archetype, policy structure diagram, learning laboratory*

Exercise 5

Illustrate the flow of resources in the case of lighting servitization from an urban area. Use the examples from Figure 8 and Figure 9 as inspirational sources. After that, apply the servitization concept on the current business model of your organization. Highlight the innovations required in this respect.

Exercise 6

Make a list with the components belonging to the natural capital (see all world's stocks of natural assets which include geology, soil, air, water and all living things) that would be affected by the business of your organization. Indicate which of these components are affected by the economic activity of your organization and propose cost-effective measures for diminishing negative effects.

Exercise 7

Consider you have to apply the transparency principle for the business of your organization. Elaborate a list with items that require traceability in this particular case and which later would be nice being monitored via an integrated software platform.

Exercise 8

Select a product that is manufactured by your company or, as an alternative, any product you like. Analyse it from the perspective of circular economy principles. Propose improvements for easy disassembly and sorting of components at the end-of-life of the considered product.

Exercise 9

Integrate the business of your organization into the circular economy concept. Draw the flow of resources in this case, using as guiding lines Figure 1, Figure 2 and Figure 4.

Exercise 10

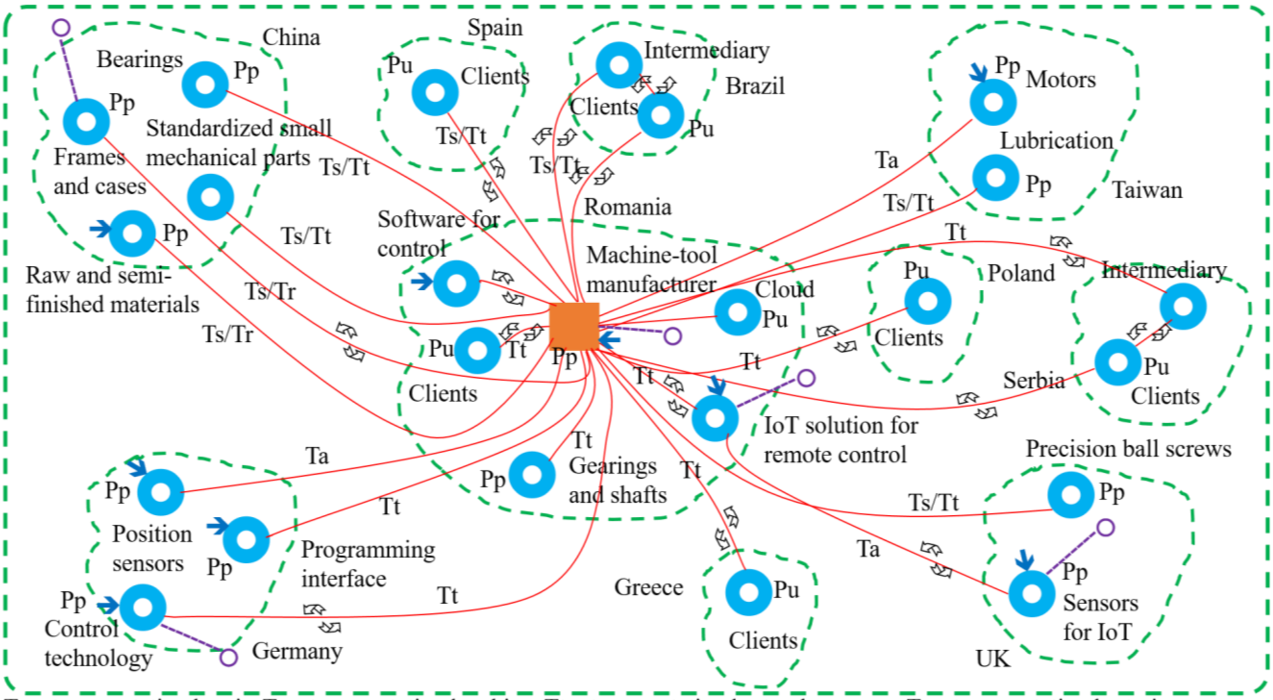
Draw the ecosystem of your organization from a system thinking perspective, indicating all key stakeholders, external factors, feedback loops, system boundaries, relationship links and systemic interventions. In this respect, use the symbols from Table 5. An inspirational example is annexed in Figure 11.

Table 5. List of symbols used in system thinking

Symbol	Meaning	Description
■	Your organization	It is the central part of the system
○	Stakeholder in the value chain	Regulators, clients, NGOs, technology providers, communities, suppliers, distributors, cluster initiatives, universities, administration
➔	External factor	Environmental constrains, consumer preferences, policy and regulations, advances in technology
⮌ ⮎	Feedback loop	New communication channels, new partnerships, customer feedback, reuse of materials, recycling of materials, shared value and wider social value

	System boundaries	Sector market, geographical area of influence
	Relationship link	Contractual transactions, knowledge exchange, business support, community relationship
	Systemic intervention	New inputs changes in outputs, policies changes, product innovation, service innovation, business model innovation, new standards, implement new materials, implement new platforms, reshape supply, new user demand, new rating schemes

Illustrative example (not all details are included):



Ta – transportation by air; Ts – transportation by ships; Tt – transportation by trucks or cars; Tr – transportation by train
Pp – pollution from production; Pu – pollution from usage

Figure 11. Example of a system thinking diagram

Exercise 11

We have the situation from Figure 12. Which is the value of marginal social cost in the point where marginal private cost equals price? Which should be the quantity (output) of goods such as the marginal social cost equals price of goods?

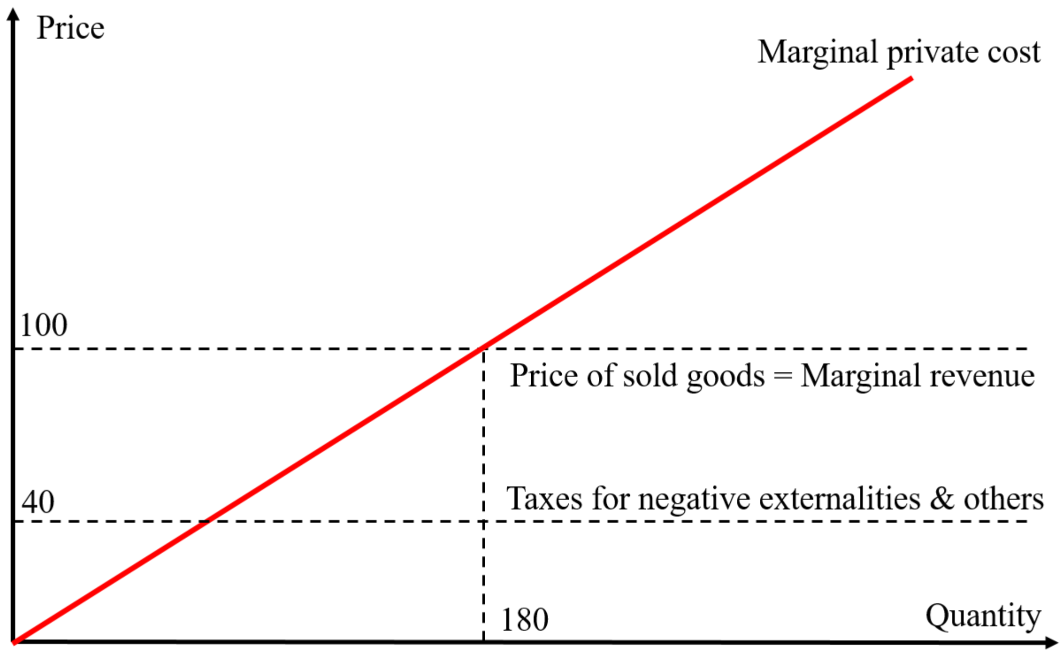


Figure 12. Explicative diagram for the exercise

Exercise 12

A company receives from a supplier parts that are packaged in wooden boxes. This company is aware of value optimization principle promoted by circular economy and decides to use the wooden plates from the boxes to design and manufacture internally customized boxes to store some of their finished products in the warehouse before delivery to customers. Thus, the company does not consume new wood or other materials to manufacture its customized boxes and reduces the environmental waste. However, company decides to make an economic calculation to see if this initiative makes sense. From 10 wooden packages, company can manufacture 20 customized boxes. Manufacturing of customized boxes has a small series production specificity. To manufacture 20 customized boxes company would spend 40 man-hours. In the EU country "Y", where company operates, the man-hour rate is 35 €/hour, from which 51% represents taxes on labour (note: see the current situation in EU). Other parts integrated into 20 customized boxes cost 50 €. To buy the plywood quantity necessary for 20 customized boxes means 20 € in a non-EU Eastern country, named "X". The man-hour rate in the country "X" is 4 €/hour and to transport 20 boxes from country "X" to country "Y" is about 200 €. Is the initiative of the company towards circular economy economically viable, or not? If not, what should be changed in the EU public policies such as this initiative to become economically viable?

Exercise 13

Figure 13 illustrates the mechanism for optimizing value creation in a circular economy. Fill in the boxes from Table 6 the current state for the case of your company and propose improvements.

Figure 13. The value creation mechanism in circular economy

(source: RSA, with modifications)

Table 6. Issues to be completed in exercise 13

Issue	Current practices	Realistic short-term improvements	Possible mid-term improvements
Design for longevity			
Design for leasing & service (or servitization)			
Design for reuse			
Design for parts recovery			
Design for recycling of disposed parts			
Design for clean manufacturing and production			
Design for more locally-based supply chain			
Design for green packaging			
Design for remote monitoring & servicing			
R&D for circular economy			

Collaboration with customers for circular economy			
Branding for circular economy			
Lobbying for circular economy			
Value chain optimization for circular economy			
Mastering economics of negative externalities			

Exercise 14

Figure 14 illustrates an exploded view of a pocket driller with the following components: (1) DC 6V motor; (2) speed reduction gearing; (3) washer; (4) chuck; (5) right half ABS plastic shell; (6) LED lens; (7) DUAL withe LED's; (8) rubber coated plastic frame; (9) trigger control: stop-left-right rotation; (10) plastic connector; (11) electronic board; (12) charging connection; (13) charging indicator; (14) DC 6V battery; (15) left half ABS plastic shell; (16) wires; (17) screw. Elaborate solutions that meet the stewardship principle of circular economy and mention results in Table 7.

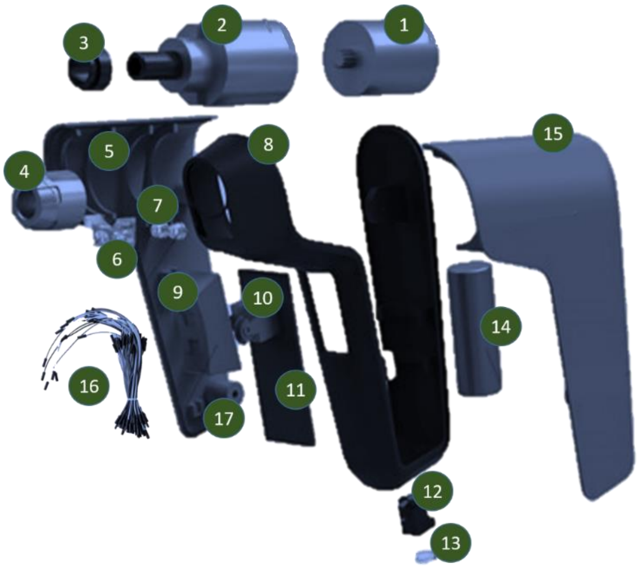


Figure 14. Exploded view of a pocket driller (source: Simon Fredriksson, with modifications)

Table 7. Guiding line to solve exercise 14

Line of intervention	Product's components involved	Proposed strategy
Product servicing at consumers during usage		
Product recovery from consumers at the end-of-life		
Components reconditioned, refurbished and reused		
Components recycled		
Components disposed		

Product redesign to support a cleaner and cost-effective manufacturing and assembly of the product [optional task]		
Product redesign to use less materials [optional task]		
Product redesign to eventually use some components of the driller for a hair dryer, too [optional task]		

Case study

Registration no. of the document: 197 / 15.05.2018

Name of the company: ROMBAT SA, Bistrița, Romania; https://www.rombat.ro/en/home/

Field of activity: Design, development, production and marketing of automotive and industrial batteries

Products: Lead-acid based batteries for automotive and industrial applications

The matrix below highlights the core principles of circular economy according to BS 8001:2017. We would like to ask you to check in the matrix, for each principle, the position that best describes the state of your company in terms of progress according to the requirements of this standard.

	Not approached	Starting	Growing	Maturing	Refining
System thinking	No evidence of system thinking ❒	Some techniques* of system thinking are applied in some projects ❒	There is a vision for circular economy activity and some activities constantly reflect resource management in relation with the value chain and wider system ☑	System thinking techniques are widely used to analyse and design any activity in organization and causality linkages and feedback loops are functional to properly progress vision, strategy and objectives related to circular economy ❒	It is demonstrated that system thinking is routinely applied in organization at all levels, optimization at product and process level is clearly demonstrated with respect to circular economy principles and staff is well trained in practical tools for circular economy ❒
Innovation	Innovation is sporadic, based on reaction to opportunities, not proactive ❒	Some principles of circular economy are seen in the linkages with customers and future business strategy ❒	Top-level management is committed to innovation driven by circular economy principles and these innovations visibly integrate all stakeholders in the value chain with tight loops ☑	There are structures and staff in the organization that are responsible to continuously improve circular economy practices in all key activities, impact is constantly monitored and all social costs due to negative externalities are supported by organization ❒	It is demonstrated a sustainable management of resources and creation of business value through adequate product and service innovation, organization being involved in business model innovation for creating new value streams towards circular economy ❒
Stewardship	No focus on recycling and disposal ❒	Knowledge about the direct and indirect impact of environment generated by organization are administrated and efforts to improve resource management are demonstrated ❒	Decisions take into account environmental and social risks and opportunities, and preoccupations to improve resource management are clearly identified, but little issues beyond the	Environmental and social risks and opportunities are well defined and understood across the whole value chain and resource management fully considers these issues; in addition,	It is demonstrated that direct and indirect impact of company's activities across the value chain is managed with responsibility and effective actions are undertaken to tackle

			direct control of organization are undertaken ☑	some indirect issues are also managed ❐	risks and harmful effects ❐
Collaboration	Collaboration is limited to transactions with suppliers and distributors ❐	Some considerations are in place that show how organization can collaborate with other parties to explore in partnership models of circular economy; most of these actions are limited to suppliers and customers ❐	There are in place all elements for a functional collaborative approach to support circular economy but its application is only partial both in the organization and in relation with stakeholders in the value chain ☑	Collaboration with stakeholders towards circular economy is functional and the related processes can be easily identified and known ❐	Collaboration to enhance application of circular economy paradigm is happening with all stakeholders ❐
Value optimization	Focus is on financial indicators and no preoccupation on life-cycle management and servitisation models ❐	Some considerations are given to the management of resources in relation with products and services, with a special focus on value related to the end of life and reduction of waste and harmful effects of the disposed waste in nature ☑	Value optimization is recognized by employees, with clear processes in place for most of the phases (design, production, end-of-life) ❐	There are implemented effective tools to optimize value, including those activities done with other parties, and resource management is seen from a systemic perspective ❐	It can be demonstrated that products, materials and components are kept at their highest value and utility in all phases of their life-time and negative externalities are minimized ❐
Transparency	Resources and not managed based on IT systems and information about resource management are poor disseminated internally and externally ❐	Information about the management of key resources related to aspects of their value is understood and basic information about recyclability of some materials delivered to customers can be provided on request ☑	Transparency in relation with circular economy is accepted by the top management and systems to manage this issue are prepared, but most of the actions are rather passive or reactive than proactive ❐	Visibility of information about resources and their impacts is actively planned and there are effective processes in place to offer such information to any third party, including partners and clients, about the circular economy activities ❐	Solutions are in place to deliver complete information about resource value from all upstream partners and to provide proper advices to all downstream partners to maximize the value of resources at the end of their use ❐

For each principle, please enumerate in a very synthetic way which are the practices we currently apply in the company (e.g. standards, procedures, software tools, technologies, processes, etc.).

Principle	Current practices applied in the company
System thinking	- Planning objectives, targets, indicators - Annual reports on CO_2 and green-house gases are elaborated (both at the level of company [Rombat] and group level [Metair] - Trimestral reports on sustainability are elaborated - Context analysis based on SWOT, PESTEL and Deming cycle - Analyses to set up objectives and KPIs based on risk assessment - Risk analyses are done at managerial level and process levels (by process coordinators) - Future plans are to extend analysis using risk-based thinking methods - To minimize waste, intelligent management of resources is done by defining maximal norms of consumption, energetic audits, material waste audits, water waste audits within processes (with focus on recycling and reuse in the internal processes) - To minimize the quantity of material used by design optimization, Rombat currently redesigns its portfolio of batteries and runs new projects; in the design projects new materials and technologies are identified based on the following criteria: less energy used, less raw materials, less weight, the same or higher performance - To eliminate or reduce the quantity of toxic materials, regulations such as REACH and CLP are considered as guiding rules in design - At the withdrawal of used batteries Rombat applies a collection and recycling system since 2002; in this respect, Rombat has a working point at Copsa-Mica (a town in the

Principle	Current practices applied in the company
	centre of Romania), where recovers over 10.000 t of Pb and polypropylene from the used batteries and uses these materials as supplementary sources of raw materials
Innovation	- Currently, Rombat applies BS EN 50342 standard for batteries, as well as internal norms that exceed this standard to meet customer requirements - In addition, Rombat applies the following standards: SR EN ISO 9001:2015 for quality management, IATF 16949:2016 for quality performance in the automotive sector, SR EN ISO 14001:2015 for environmental issues management, BS OHSAS 18001:2007 for occupational safety and SR EN ISO 45001:2018, as well the social standard SA 8000:2014 - Specialized software is mainly used for risk management in product and process design (FMEA), as well as for statistical and process capability analysis; to these, SAP system is implemented for production planning, stocks and material management - There is no dedicated full-time position of manager responsible with circular economy, but the manager responsible with environmental issues monitors this dimension of the business - In the area of monitoring negative externalities, Rombat respects the regulation imposed by the authorization for integrated environment protection - Yet there are no special social interventions to compensate negative externalities, but maximal limits for environmental impact are imposed within the environmental management system (SR EN ISO 14001:2015) - Still, there is no structured model to tackle circular economy such as cradle-to-cradle or industrial ecology, but steps towards such models is present in the company: purchasing of equipments and technologies considers ecological issues; use of recycled materials is considered whenever possible; minimization of waste materials in processes is considered - Continuous improvement in relation with waste recovery, recycling and reuse as raw materials is done by collaboration with dedicated centres where batteries are distributed (from Craiova, Constanta and Bucharest), as well as with Rombat distributors. Rombat collects used batteries from population, too - Value added by reuse of recycled materials is done in Rombat by recovering 100% Pb from the used batteries and 90% of the polypropylene - In Rombat, the concept "recover-recycle-redesign-reduce-remanufacture-reuse" is very well applied in recover-recycle-reuse (in 2017, 83,3% from the materials in used batteries were recovered and reused); the redesign-remanufacture part of the concept is in consideration within the new projects
Stewardship	- To reduce environmental impact, Rombat practices include: keeping within the limits imposed in annual environmental plans; redesign the batteries; maintaining and improving the buy-back program of used batteries; optimization of supply with raw materials; optimization of stocks - Environmental impact is measured by measuring gas emissions, followed up by improvement action plans - The concept of "extended producer responsibility" is embedded within company's mission and put into practice by CSR and better relationships with distributors and consumers
Collaboration	- Suppliers are integrated in the process of circular economy by delivering raw materials and semi-processed materials in recyclable packages or reusable and returnable packages - Customers and distributors are integrated in the process of circular economy by recovering for recycling of used batteries (using a storage system); also, packages of new batteries are recovered for reuse or recycling for further valorisation by Rombat - For battery realization, Rombat involves customers in the design and production processes (co-design and control), but also the suppliers
Value optimization	- Stock of materials is managed with FiFo method - Future plans include actions to increase the speed of inventory rotation, as well as negotiation of the most important raw materials

Principle	Current practices applied in the company
	- Servitization model is not yet implemented in Rombat, but service representatives are present across the country - Life-cycle management of batteries is mainly focused on the withdrawal phase; still, opportunities for remote monitoring of batteries over the exploitation phase can be considered (e.g. designing smart batteries with IoT features) - CO_2 reduction over battery life-cycle is done by using special materials with low footprint on environment; steps forward are investigated to reduce the quantity of materials in the new designs
Transparency	- Every year, Rombat submit at the Environmental Agency a report with all monitoring activities done over the year; reports are published for the general public - On the Rombat's website general public can get information about batteries, guaranty certificates, instructions for use

Filled in by: Eng. Marin Lantos, Manager TQM / Rombat S.A – Bistrita

4. QUESTIONS & ANSWERS

4.1. QUIZ – QUESTIONS

1. Which of the next statements better expresses the scope of circular economy?

❒ Circular economy is about recycling and recovering of materials from products at the end of their life

❒ Circular economy is about minimization and responsible use of input resources, minimization of output waste and achievement of highest possible value from products during their usage phase by tight loops of resource management

❒ Circular economy is about management of natural and technical ecosystems in closed loops

2. Why system thinking is so important in implementing circular economy paradigm?

❒ System thinking helps to analyse circular economy as a system

❒ System thinking shows how various systems in the wider ecosystem are interrelated and approaches the design of a new system considering its implications on the other systems and considering the constrains and dynamics of the other systems

❒ System thinking encourages engineers and decision markers to design and develop products from a life-cycle perspective

3. What types of innovations are mainly promoted by circular economy?

❒ Circular economy promotes green design of products and related processes

❒ Circular economy promotes any type of innovation, from product innovation to process innovation and ending with business model innovation

❒ Circular economy promotes any kind of innovation that reduces waste and/or generates value added from waste in terms of social costs

4. How stewardship principle can be more effective implemented?

- ❐ Effective implementation of stewardship is by adopting national and international regulations that encourage circular economy
- ❐ Effective implementation of stewardship is by extra-taxation of materials, energy, transportation, and under-taxation of workforce
- ❐ Effective implementation of stewardship is by imposing buy-back rules to all producers

5. Which is the key trigger for optimizing value in circular economy?

- ❐ The key trigger is reduction of CO_2 emissions
- ❐ The key trigger is minimization of waste generation and maximization of waste reutilization
- ❐ The key trigger is generation of new revenue streams from application of novel business models such as leasing, renting and servitization

6. How collaboration between organizations is seen in circular economy?

- ❐ Collaboration between organizations in circular economy is under the form of strategic alliances such as to better handling waste and transform it into new inputs for new applications
- ❐ Collaboration between organizations in circular economy is a necessity in every stage of product life-cycle such as to maximize value for each member in the value chain
- ❐ Collaboration between organizations in circular economy is required to ensure suitability and innovation of materials

7. Why is it necessary to be transparent when implement circular economy paradigm?

- ❐ Transparency is necessary to ensure traceability of materials that companies use, where they come from and who made them
- ❐ Transparency is necessary to demonstrate to any third party that you are aware of circular economy and implement it in a correct manner
- ❐ Transparency is necessary to optimize value creation to the level of all stakeholders in the value chain of circular economy

8. How could we integrate natural capital in the economic model?

- ❐ Natural capital can be integrated in the economic model of a business by taxation of services provided by natural capital in relation with the respective business
- ❐ We cannot integrate natural capital in the economic model of a business
- ❐ Natural capital can be integrated in the economic model of a business by taxation of consumers

9. Which is the most critical aspect in optimizing resource yields?

- ❐ The most critical aspect in optimizing resource yields is the adequate design of products for easy manufacturing, easy monitoring and maintenance, easy upgrading, easy disassembly
- ❐ The most critical aspect in optimizing resource yields is the composition of materials incorporated in the product

❐ The most critical aspect in optimizing resource yields is the business model of the original product manufacturer

10. Who should monitor and assess negative externalities of every economic activity such as to ensure the social costs are minimized? Argue the selected variant.

❐ Governmental agencies, because ____

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❐ Companies themselves, because ____

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❐ Third parties paid for social services, because ____

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4.2. QUIZ – SOLUTIONS

1. Which of the next statements better expresses the scope of circular economy?
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☒ Circular economy is about minimization and responsible use of input resources, minimization of output waste and achievement of highest possible value from products during their usage phase by tight loops of resource management
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❒ System thinking helps to analyse circular economy as a system
☒ System thinking shows how various systems in the wider ecosystem are interrelated and approaches the design of a new system considering its implications on the other systems and considering the constrains and dynamics of the other systems
❒ System thinking encourages engineers and decision markers to design and develop products from a life-cycle perspective

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❒ Circular economy promotes green design of products and related processes
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6. How collaboration between organizations is seen in circular economy?
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☒ Collaboration between organizations in circular economy is a necessity in every stage of product life-cycle such as to maximize value for each member in the value chain
❒ Collaboration between organizations in circular economy is required to ensure suitability and innovation of materials

7. Why is it necessary to be transparent when implement circular economy paradigm?
❒ Transparency is necessary to ensure traceability of materials that companies use, where they come from and who made them
❒ Transparency is necessary to demonstrate to any third party that you are aware of circular economy and implement it in a correct manner
☒ Transparency is necessary to optimize value creation to the level of all stakeholders in the value chain of circular economy

8. How could we integrate natural capital in the economic model?

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❒ We cannot integrate natural capital in the economic model of a business

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9. Which is the most critical aspect in optimizing resource yields?

☒ The most critical aspect in optimizing resource yields is the adequate design of products for easy manufacturing, easy monitoring and maintenance, easy upgrading, easy disassembly

❒ The most critical aspect in optimizing resource yields is the composition of materials incorporated in the product

❒ The most critical aspect in optimizing resource yields is the business model of the original product manufacturer

10. Who should monitor and assess negative externalities of every economic activity such as to ensure the social costs are minimized? Argue the selected variant.

❒ Governmental agencies, because ____

❒ Companies themselves, because ____

☒ Third parties paid for social services, because it is the most effective business model to close the circle.

5. GLOSSARY

- **Bio-based material**: ""Bio-"is Greek for life. Bio-based material refers to a products main constituent consisting of a substance, or substances, originally derived from living organisms. These substances may be natural or synthesized organic compounds that exist in nature. This definition could include natural materials such as leather and wood, but typically refers to modern materials. Many of the modern innovations use bio-based materials to create products that biodegrade. Some examples are: cornstarch, derived from a grain and now being used in the creation of packaging pellets; bio-plastics created with soybean oil, now being used in the creation of many modern products like tractors, water bottles, and take away cutlery." [1] **Biodegradable material**: "A material which microorganisms can break down into natural elements (i.e. water, biomass, etc.)."[2]
- **Biological metabolism** - The natural processes of ecosystems are a biological metabolism, making safe and healthy use of materials in cycles of abundance[3]
- **Biological Nutrient** - A material used by living organisms or cells to carry on life processes such as growth, cell division, synthesis of carbohydrates and other complex functions. Biological Nutrients are materials that can biodegrade safely and return to the soil to feed environmental processes[4]
- **Cascading**: see MOVECO fact sheet "Circular Economy: Terms & Definitions"
- **Compostable material**: "Materials that can be disposed with biological materials and decay into nutrient-rich material."[5] **Circular economy** - regenerative economy in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing energy and material loops
- **Cradle-to-Cradle®**: see MOVECO fact sheet "Supporting Tools for a Circular Economy"
- **Cradle to Grave** – "A Cradle to Grave system is a linear model for materials that begins with resource extraction, moves to product manufacturing, and, ends with a "grave" – when the product is disposed of in a landfill or incinerator"[6]
- **Decision** – "shall be binding in its entirety. A decision which specifies those to whom it is addressed shall be binding only on them"[7]
- **Directive** – "shall be binding, as to the result to be achieved, upon each Member State to which it is addressed, but shall leave to the national authorities the choice of form and methods"[8]

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[1] https://sustainabilitydictionary.com/2006/02/17/bio-based-material/ (26.03.2018) // "A material that is partially, or entirely made of biomass." https://www.ceguide.org/Glossary (26.03.2018)
[2] https://www.ceguide.org/Glossary (26.03.2018)
[3] Cradle to Cradle terminology – MBDC-http://www.c2cproducts.com/detail.aspx?linkid=1&sublink=26
[4] Cradle to Cradle terminology – MBDC-http://www.c2cproducts.com/detail.aspx?linkid=1&sublink=26
[5] https://www.ceguide.org/Glossary (26.03.2018)
[6] Cradle to Cradle terminology – MBDC-http://www.c2cproducts.com/detail.aspx?linkid=1&sublink=26
[7] European Network of Environmental law Organizations 2012 Implementation of the Waste Framework Directive in the EU Member States
[8] European Network of Environmental law Organisations 2012 Implementation of the Waste Framework Directive in the EU Member States

- **Down-cycle** - to recycle (something) in such a way that the resulting product is of a lower value than the original item : to create an object of lesser value from (a discarded object of higher value)[9] see: MOVECO fact sheet "Circular Economy: Terms & Definitions"
- **Eco-Effectiveness** – "The central strategy in the cradle-to-cradle development method and seeks to create industrial systems that emulate healthy natural systems. The central principle of eco-effectiveness is that "waste equals food." The concept was developed in response to some of the perceived limitations of eco-efficiency which critics claim only slow down the rate of environmental depletion and don't reverse the production of unused or non-recycled waste".[10]
- **Eco efficiency** – "Management philosophy that aims at minimizing ecological damage while maximizing efficiency of the firm's production processes, such as through the lesser use of energy, material, and water, more recycling, and elimination of hazardous emissions or by-products."[11]
- **Ecological sustainability** – "a bio-centric school of sustainability thinking that, based on ecology and living systems principles, focuses on the capacity of ecosystems to maintain their essential functions and processes, and retain their biodiversity in full measure over the long-term contrasts with technological sustainability based on technical and engineering approaches to sustainability"[12]
- **Ecosystem** - the interactive system of living things and their non-living habitat[13]
- **Ecosystem redesign** - a coherent framework for redesigning our landscapes, buildings, cities, and systems of energy, water, food, manufacturing and waste through the effective adaptation to and integration with nature's processes[14]
- **Energy efficiency**: "Energy efficiency improvements refer to a reduction in the energy used for a given service (heating, lighting, etc.) or level of activity. The reduction in the energy consumption is usually associated with technological changes, but not always since it can also result from better organisation and management or behavioral changes ("non-technical factors")."[15]
- **Energetic use**: incineration of waste material that includes the use of the generated heat and energy for other processes
- **(Final) disposal**: see MOVECO fact sheet "Circular Economy: Terms & Definitions"

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[9] Merriam Webster dictionary
[10] https://sustainabilitydictionary.com/2005/12/03/eco-effectiveness/visited 26/02/2018
[11] http://www.businessdictionary.com/definition/eco-efficiency.html -visited 01.03.2018
[12] Orr D (1992) Ecological literacy: education and the transition to a post-modern world. State University of New York Press, Albany.
[13] Tansley AG (1935) The use and abuse of vegetational concepts and terms. Ecology 16:284–307 doi:10.2307/1930070
[14] with adaptations from https://www.researchgate.net/publication/301966198_Regenerative_Development_regenerative_development_and_Design (26.06.2018)
[15] https://hub.globalccsinstitute.com/publications/energy-efficiency-recipe-success/definition-and-scope-energy-efficiency (26.03.2018)

- **Incineration**: Waste destruction in a furnace by controlled burning at high temperatures. Incineration removes water from hazardous sludge, reduces its mass and/or volume, and converts it to a non-burnable ash that can be safely disposed of on land, in some waters, or in underground pits. However, it is a highly contentious method because incomplete incineration can produce carbon monoxide gas, gaseous dioxins, and/or other harmful substances.[16]
- **Innovation** - production or adoption, assimilation, and exploitation of a value-added novelty in economic and social areas[17]
- **Landfilling**: "The disposal and burying of solid waste. The degradation of the waste results in the creation of local air and water pollution."[18]
- **Lean production** - approach to management that focuses on cutting out waste, whilst ensuring quality[19]
- **Life-cycle** - series of stages in form and functional activity through which a system passes between successive recurrences of a specified primary stage[20]
- **Life-cycle analysis**: see MOVECO fact sheet "Supporting Tools for a Circular Economy"
- **Life-time** - the duration of the existence of a given particular system[21]
- **Locational patterns** - the patterns that depict the distinctive character and potential of a place and provide a dynamic mapping for designing human structures and systems that align with the living systems of a place[22]
- **Negative externality** - occurs when production and/or consumption imposes external costs on third parties outside of the market for which no appropriate compensation is paid[23]
- **Optimization** - finding an alternative with the most cost effective or highest achievable performance under the given constraints, by maximizing desired factors and minimizing undesired ones[24]
- **Permaculture** - a system of agricultural and social design principles centered around simulating or directly utilizing the patterns and features observed in natural ecosystems[25]
- **Place** - the unique, multi-layered network of ecosystems within a geographic region that results from the complex interactions through time of the natural ecology (climate, mineral and other deposits, soil, vegetation, water and wildlife, etc.) and culture (distinctive customs,

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[16] http://www.businessdictionary.com/definition/incineration.html (27.06.2018)
[17] with adaptations from http://www.ericshaver.com/the-many-definitions-of-innovation/ (27.06.2018)
[18] https://www.ceguide.org/Glossary (26.03.2018)
[19] with adaptations from https://www.tutor2u.net/business/reference/introduction-to-lean-production (27.06.2018)
[20] https://www.merriam-webster.com/dictionary/life%20cycle (26.06.2018)
[21] With adaptations from https://en.wikipedia.org/wiki/Lifetime (26.06.2018)
[22] https://www.researchgate.net/publication/273379786_Regenerative_Development_and_Design (25.06.2018)
[23] with adaptations from https://www.economicshelp.org/micro-economic-essays/marketfailure/negative-externality/ (26.06.2018)
[24] http://www.businessdictionary.com/definition/optimization.html (26.06.2018)
[25] https://en.wikipedia.org/wiki/Permaculture (27.06.2018)

expressions of values, economic activities, forms of association, ideas for education, traditions, etc.)[26]

- **Recommendations and opinions** - shall have no binding force [27]
- **Recycling:** see MOVECO fact sheet "Circular Economy: Terms & Definitions"
- **Refurbishment:** "The refurbishment of something is the act or process of cleaning it, decorating it, and providing it with new equipment or facilities."[28]
- **Regenerative design** - a system of technologies and strategies, based on an understanding of the inner working of ecosystems that generates designs to regenerate rather than deplete underlying life support systems and resources within socio-ecological wholes[29]
- **Regenerative development** - a system of technologies and strategies for generating the patterned whole system understanding of a place, and developing the strategic systemic thinking capacities, and the stakeholder engagement/commitment required to ensure regenerative design processes to achieve maximum systemic leverage and support, that is self-organizing and self-evolving[30]
- **Regulation** - shall have general application. It shall be binding in its entirety and directly applicable in all Member States. – Source - Article 288 TFEU, [31]
- **Remanufacturing:** "The process of cleaning and repairing used products and parts to be used again for replacements."[32]
- **Restorative design** - sometimes called restorative environmental design; a design system that combines returning polluted, degraded or damaged sites back to a state of acceptable health through human intervention[33]
- **Resource efficiency**: "A percentage of the total resources consumed that make up the final product or service."[34] re-use: see MOVECO fact sheet "Circular Economy: Terms & Definitions"
- **Secondary resource/ secondary raw materials:** "Waste materials that are recovered, recycled and reprocessed for use as raw materials."[35]
- **Servitization** - refers to industries using their products to sell "outcome as a service" rather than a one-off sale[36]

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[26] https://www.researchgate.net/publication/273379786_Regenerative_Development_and_Design (25.06.2018)
[27] http://eur-lex.europa.eu/summary/chapter/environment.html?root_default=SUM_1_CODED%3D20,SUM_2_CODED%3D2003&locale=en
[28] https://www.collinsdictionary.com/de/worterbuch/englisch/refurbishment (26.03.2018)
[29] Mang, Pamela & Reed, Bill. (2017). Update Regenerative Development and Design 2nd edition.
[30] https://www.sciencedirect.com/science/article/pii/S2212609015300327 (26.06.2018)
[31] http://eur-lex.europa.eu/legal-content/en/TXT/HTML/?uri=CELEX:12016E288
[32] https://sustainabilitydictionary.com/2005/12/03/remanufacturing/ (26.03.2018)
[33] https://www.researchgate.net/publication/273379786_Regenerative_Development_and_Design (24.06.2018)
[34] https://sustainabilitydictionary.com/2005/12/03/remanufacturing/ (26.03.2018)
[35] https://sustainabilitydictionary.com/2005/12/03/remanufacturing/ (26.03.2018)
[36] https://www.k3syspro.com/servitization/ (24.06.2018)

- **Source to sink** - simple linear flows from resource sources (farms, mines, forests, watershed, oilfields, etc.) to sinks (air, water, land) that deplete global sources and overload/pollute global sinks[37]
- **Stewardship** - ethic of companies, organizations and individuals that embodies the responsible planning and management of resources[38]
- **Sourcing:** "the act of getting something, especially products or materials, from a particular place"[39]
- **System thinking** - holistic approach of analysis and planning that focuses on the way the parts of a system interrelate each other and how systems work over time and within the context of larger systems[40]
- **Technical metabolism** - "Modelled on natural systems, the technical metabolism is MBDC's term for the processes of human industry that maintain and perpetually reuse valuable synthetic and mineral materials in closed loops"[41]
- **Technical nutrient** – "A material that remains in a closed-loop system of manufacture, reuse, and recovery called the technical metabolism, maintaining its value through infinite product life cycles "[42]
- **Upcycle** – "to recycle (something) in such a way that the resulting product is of a higher value than the original item: to create an object of greater value from (a discarded object of lesser value)"[43]
- **Upcycling**: see MOVECO fact sheet "Circular Economy: Terms & Definitions"
- **Waste**: see MOVECO fact sheet "Circular Economy: Terms & Definitions"

More: https://www.ceguide.org/Glossary

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Essential reading

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[37] https://www.researchgate.net/publication/273379786_Regenerative_Development_and_Design (25.06.2018)
[38] https://en.wikipedia.org/wiki/Stewardship (24.06.2018)
[39] https://dictionary.cambridge.org/dictionary/english/sourcing (26.03.2018)
[40] https://searchcio.techtarget.com/definition/systems-thinking (27.06.2018)
[41] Cradle to Cradle terminology – MBDC-http://www.c2cproducts.com/detail.aspx?linkid=1&sublink=26
[42] Cradle to Cradle terminology – MBDC-http://www.c2cproducts.com/detail.aspx?linkid=1&sublink=26
[43] Merriam Webster dictionary

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(Pauiliuk 2018) Stefan Pauiliuk: Critical appraisal of the circular economy standard BS 8001:2017 and a dashboard of quantitative system indicators for its implementation in organizations. Resource, Conservation and Recycling 129 (2018). 81-92. 2018.

(Ritzen 2017) Sofia Ritzen, Gunilla Ölundh Sandstrom: Barriers to the circular economy – integration of perspectives and domains. Procedia CIRP 64 (2017). 2-17. 2017.

Further reading

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(Preston 2017) Felix Preston., Johanna Lehne: The circular economy in developing countries. Chathman House. The Royal Institute of International Affairs. 2017.

Other online recommended sources

1. https://www.circulardesignguide.com/methods
2. https://www.burgehugheswalsh.co.uk/systems-thinking/tools.aspx

Online video sources

1. CNBC International. What is the circular economy? https://youtu.be/__0Spwj8DkM
2. EU Environment. How to become a green SME in a circular economy. https://youtu.be/V1Tszs48xCI
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7. IMPRINT

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