ECOLE:

ECO industrial park network for the Alpine Regions Leveraging smart and Circular Economy

Paper on Eco Industrial Park concept int the Alpine regions

Deliverable D.1.1.2

Produced by

PPT 11: FLA

This project is co-funded by the European Union through the Interreg Alpine Space programme.

Project-ID: ASP0100091

ECO industrial park network for the Alpine Regions **L**everaging smart and Circular **E**conomy

Document Details	
Project acronym	**ECOLE**
Project title	**ECO industrial park network for the Alpine Regions Leveraging smart and Circular Economy**
Project ID	**ASP0100091**
Project budget	**€ 2,591,200.00**
Action	**Act.1.1 Define a common understanding & framework of the EIPs & circular economy approach for the Alpine region**
Deliverable	**D.1.1.2 Paper on Eco Industrial Park concept in the Alpine regions**
Due date	**2023.03**
Delivery date	**2023.07.15**
Dissemination	**PPs**
Partner in charge	**PP11 – FLA**
Author(s)	**Massimo Di Domenico and Mita Lapi**

Short Description
Paper on EIPs that conserve resources, reduce production, increase energy & operating efficiency, people wellbeing, public image & provide opportunities for sustainable development

Dissemination level		
PU	Public	x
PP	Restricted to other programme participants	
RE	Restricted to a group specified by the consortium	

CO	Confidential, only for members of the consortium	

Revision history			
Version	**Date**	**Author**	**Organization**
V1.0	17.02.2023	Massimo Di Domenico	FLA
V1.1	24.02.23	Massimo Di Domenico	FLA
V.1.2	07.07.23	Massimo Di Domenico	FLA
Final Document	15.07.23	Massimo Di Domenico	FLA

The document has been prepared by the project partners of the Interreg Alpine Space project ECOLE. This project is co-funded by the European Union through the Interreg Alpine Space programme. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

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PP 12 – Lombardy Foundation for the Environment (DE): TUMint

ABBREVIATIONS USED

AF	Application Form
AP	Associated Partner
AS	Alpine Space
CM	Communication Manager
ECOLE	ECO industrial park network for the Alpine Regions Leveraging smart and Circular Economy
ERDF	European Regional Development Fund
EU	European Union
JS	Joint Secretary
KPI	Key Performance Indicators
LP	Lead partner
PP	Project Partner
TL	Task Leader
TPM	Transnational Project Meeting
WP	Work Package
WPL	Work Package Leader

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1. Literature review on circularity

1.1. Introduction

The circular economy is an important factor of change in the field of sustainability, as it aims to change the traditional model of production and consumption. The goals of the circular economy are the systemic change to build long-term resilience, create business and economic opportunities, and provide social and environmental benefits through technical and biological cycles. It supports an economy where waste and pollution must be reduced through the conscious design of products, services and processes, and where the value of resources must be maintained for as long as possible. In this context, attention to the natural system is maximum and where the integrity of natural resources must take place through regeneration processes. The basic idea is linked to the need to preserve the value of natural resources over time through multiple uses within closed cycles. This reduces the pressure on the use of virgin natural resources by reducing the environmental impact (but not eliminating it). Ultimately, CE is inspired by natural patterns and natural flows of matter and energy that are based on regenerative cycles.

The growing attention to sustainability issues affects all sectors of the economic and social context. The 2030 Agenda proposed by the United Nations represents, in this context, the culmination of the commitments that have made it possible to define specific objectives of sustainable development at international level.

The 2030 Agenda pays close attention to the circular economy through the definition of multiple objectives related to:

1. Sustainable consumption and production (SDG 12),
2. tenergy (SDG 6),
3. economic growth (SDG 8),
4. sustainable cities (SDG 11),
5. climate change (SDG 13),
6. oceans and marine resources (SDG 14)
7. and life on earth (SDG 15).

The transition to the Circular Economy (CE) is now a goal promoted by European policies and implemented in many countries. Companies certainly play an important role in implementing circular actions and contributing to sustainable development.

1.2. The theoretical basis of development for the EC

The growing interest in the CE as a (sustainable) development strategy to improve the efficient use of resources and the competitiveness of companies and markets is not, however, supported by a stable theoretical framework and a set of homogeneous operational indications. In fact, various interpretations and applications for different levels (micro, meso, macro) and in different regions of the world are applied. The concept of CE has concrete theoretical roots within numerous disciplines, theories and approaches, as highlighted in the following figure. Boulding (1966) is the father of these theories and approaches highlighting the difference between open and closed systems with particular reference to three essential elements for their existence: materials, energy, information/knowledge[1].

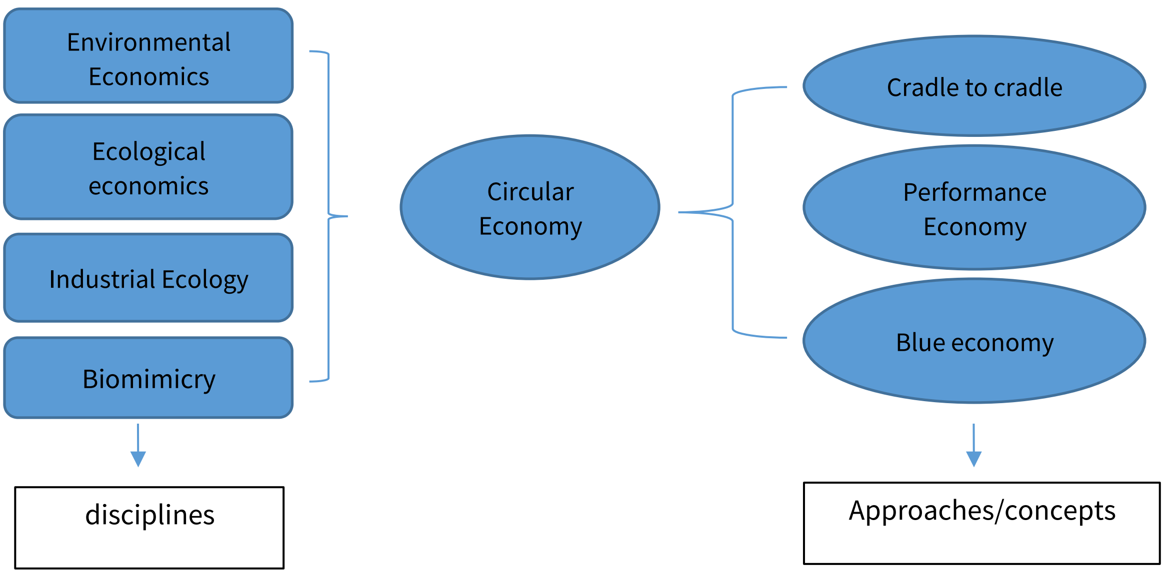

Figure 1: different approaches and theories for circularity definition

[1] These elements are also the basis of the economy, which Boulding calls "the econosphere," which he sees "as a material process involving the discovery and extraction of fossil fuels, minerals, etc., and at the other end a process by which the system's effluents are distributed in non-economic reservoirs." In other words, what is now called the "take-make-dispose" linear economy. Boulding then moves on to the concept of entropy, giving a description of the thermodynamics of a circular economy, emphasizing the importance of both energy and information.

In the above figure it is possible to acknowledge that the theories and approaches to CE are multiple. For our purposes, though, very important are Industrial Ecology, Biomimicry, Cradle to Cradle, Performance Economy, Blue Economy.[2]

Industrial Ecology is inspired by the need to rethink industrial society as an ecosystem within the biosphere. This means considering a systemic analysis for industrial processes and all its components within an environment, and how all this can be considered as part of a joint ecosystem. In this context, the functioning of the industrial system, the analysis of material and energy flows and how all this interacts with the biosphere are analyzed.

Therefore, the Industrial Economy promotes collaboration between several independent entities with the aim of creating industrial networks for the efficient management of resources. In this context, there are four key principles on which the reorganization process of an industrial ecosystem is based[3]:

1. Constant valorisation of waste and by-products. This principle is not only based on the need to initiate traditional forms of recycling but also to create sustainable networks of resources and waste so that the waste materials of one organization can become inputs for another economic entity. All this with a view to industrial symbiosis.
2. Minimization of losses caused by leakage into the environment. Reducing losses calls for the need to design and identify products and services aimed at reducing the impact on the environment.
3. Dematerialize economic processes. This principle aims to reduce the flow of total materials while maintaining an equivalent or higher level of services used. Mainly from this derives the need and the creation of opportunities aimed at creating services where the use of products becomes priority over their sale.
4. Development of renewable energy sources. The development of decentralized forms of energy production and consumption represents a new mode of energy supply that require investment in technologies for the production of renewable energy sources, accompanied

[2] We do not deal in this context with Environmental Economics which represents a particular specialization of neoclassical economics (see e.g. Pearce and Turner (1990)) and ecological economics (see for example the works of Constance *et. Al* (1991).
[3] Erkman (2001).

by energy storage systems and the development of digital support platforms (digital energy) aimed at optimizing energy flows from these sources.

Part of the Industrial Ecology approach is the application of methodologies and tools such as Life Cycle Assessment (LCA) aimed at measuring the environmental impacts of industrial products.

Biomimicry is based on the study of the solutions that nature has developed to take as an example and inspire innovative solutions for new technologies and sustainable industrial processes for society. It is based on three key principles which are:

1. *Nature as a model*, to find inspiration in ecosystems and their characterizing processes;
2. *Nature as measure,* using ecological standards to assess the sustainability of all innovations and designs;
3. *Nature as mentor*, looking at nature to learn and adapt its solutions.

For this theory a fundamental discipline is the system thinking approach, as it is necessary to consider all the possible interactions between products / services with nature and ecosystems. In this context, therefore, the CE can be seen as the application of Biomimicry at ecosystem level, in particular, with regard to the absence of waste in ecosystem processes. In other words, a system where waste organisms feed other organisms in such a way that materials circulate in cycles without contaminating the ecosystem.

Cradle to Cradle design[4] is basically an approach that considers all materials used in commercial and industrial environments as "nutrients" in turn broken down into two categories: technological and biological. In essence, the method applies the model of the biological "metabolism" of nature to the technical metabolism of the flows of industrial materials. This approach highlights how eco-efficiency, i.e. aimed at reducing the environmental impact of products and processes, is not enough, on its own, to achieve sustainable development in the medium to long term. In addition, it is necessary to move from the logic of downcycling to one of upcycling supported by adequate development of product design and innovation in the development of recycling processes and technologies. In order to increase the positive impacts determined by human production and

[4] Braungart et al. (2006).

consumption activities (eco-effectiveness), three design principles inspired by human nature and metabolism are highlighted: [5]

1. Waste equals food, a principle that indicates how all industrial products and processes are designed to allow the perpetual flow of nutrients within one of the two distinct metabolisms (cycles): biological metabolism and technical metabolism. We therefore have consumer products - consumed during their life cycle through, for example, physical degradation or abrasion (e.g. clothes, detergent products, etc.) - which, in order to be included in natural systems, should be designed for this purpose and perhaps to cause, once in the natural environment, a positive impact on resources. This implies the use of biodegradable materials, for example, to support biological cycles. In addition, there are service products, products that should circulate in closed systems (production, use, collection, recycling / reuse) without inserting themselves into natural systems. Develop, in the latter case, performance or product as a service sales systems, a strategy that allows the manufacturer to withdraw, at the end of life, technical inputs. Maintaining the ownership of the product in the hands of the companies would allow to increase the quality and durability and a design aimed at maintaining value in the different cycles;
2. use current solar income, based on the use of renewable energy sources for civil and productive uses;
3. celebrate diversity, where biodiversity and cultural and social diversity are an important prerequisite for the application of this approach.

The Performance Economy[6] is an approach that considers an economy based on closed cycles, which favors reuse, repair and remanufacturing instead of the manufacturing of new goods. In this way it can provide important benefits in terms of jobs, economic competitiveness, resource saving and waste prevention. The systemic approach considered aims to favor the sufficiency of resources rather than their efficient management with a view to finding system solutions rather

[5] Recycling is the process by which a product that has become waste is transformed into a new product. Specifically, we speak of downcycling if the material is treated to be transformed into something that has less value than the product from which it derives, or if it is necessary to add other substances to reconvert it. On the contrary, upcycling allows the material to transform into something with a higher quality and value. But perhaps the most interesting term is pre-cycling, i.e. the reduction of waste, avoiding producing it. During the design of a product you can in fact think about how to avoid the disposal of the product, for example by already planning its reuse.
[6] Sviluppata dagli studi di Stahel e Reday-Mulvey (1981).

than the search for business models. In addition, this process involves optimizing stocks and preserving and maintaining value over time. This includes extended performance responsibility, which implies a decoupling between well-being and the volume of resources produced, together with the creation of new jobs at local level. As part of this approach, important cycles include:

1. Reuse loop, which includes second-hand markets and the reuse of private and commercial goods carried out locally;
2. Loop 1, remanufacturing, aimed at extending the useful life of products through repair, remanufacturing and upgrading carried out locally or regionally;[7]
3. Loop 2- recycling aimed at considering processes that produce secondary raw materials that can be used in production activities, carried out at regional and/or global level.

The Performance economy approach is very much based on the responsibility of producers who adapt their business models in this regard, leaving consumers the role of mere users. In this way, the sale of products in the form of services or performance is the CE's main business model, which is more profitable and resource-efficient. The manufacturer therefore retains ownership of the product and responsibility for it throughout its useful life.

Finally, the **Blue Economy** represents an open-source movement aimed at inspiring entrepreneurs to create innovative business models in a local dimensional perspective regarding the availability of the resources used. The approach points to introduce competitive products and services aimed at satisfying basic needs and capable of building social and natural capital. It is based on 21 principles inspired by nature and ecosystems from which one of the fundamental ideas derives, namely, that of nutrients and cascading energy, within the limits of local availability.

The following figure illustrate concisely all the concepts related to the above approaches.

[7] Remanufacturing is an industrial practice that consists of "returning a product at least to its original performance with a warranty equivalent or better than that of the newly manufactured product; Upgrading is the improvement of the product and its functions.

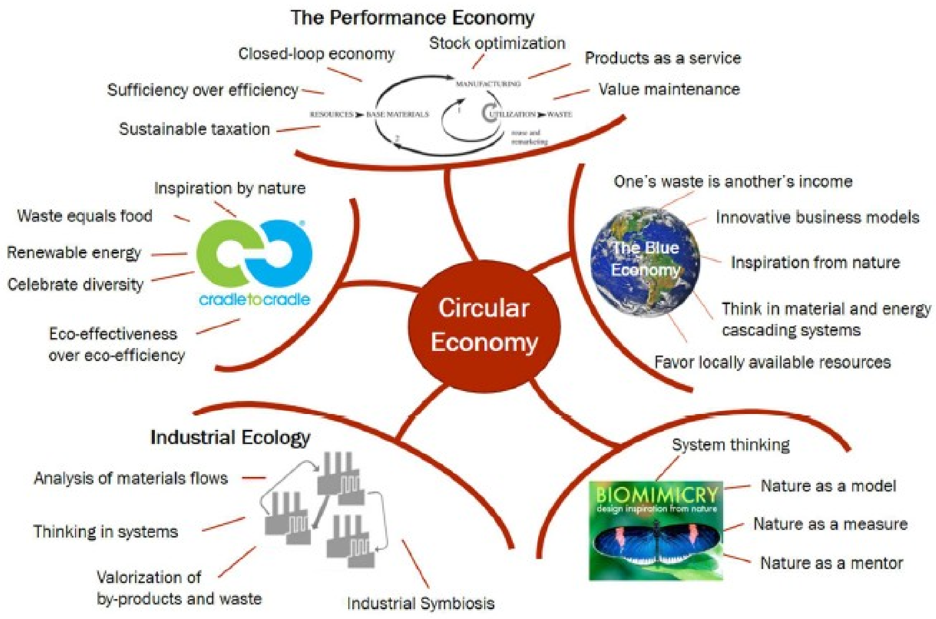

Figure 2: circular economy main approaches

The circular economy draws elements from each of these approaches, offering a composite framework of principles, objectives, solutions, rising to a generic notion, gravitating on different approaches, all of which are inspired by a series of common principles (Ellen MacArthur Foundation (2017)).

1.3. Definition and related concepts

This paragraph will highlight the main aspects of the Circular Economy and a brief definition of this concept, given however its different application in different regions of the world.

The definitions of CE are different, demonstrating that a definite and stable theoretical framework has not been developed so far. Of particular reference are the definitions of the Ellen McArthur Foundation (EMF) that we propose again:

"An industrial system that is restorative or regenerative by intention and design. It replaces the concept of "end of life" with that of restoration, marries the use of renewable energy, eliminates the use of toxic chemicals, which hinder their reuse and aims at eliminating waste through better design of materials, products, systems and, within this, business models".[8]

[8] Ellen MacArthur Foundation, 2012.

"The goal of a circular economy model is to allow an effective flow of materials, energy, labor and information so that natural and human capital are replenished."[9]

Another definition comes from Preston (2012):

"The circular economy is an approach that aims to transform the function of resources in the economy. One company's waste can become a valuable input to another process and products could be repaired, reused or upgraded rather than thrown away."[10]

With respect to the definition of EMF based on an organic language (restorative and regenerative) and linked to the concepts of ecology and symbiosis, Kirchherr *et al.* (2017) define the CE as an economic system (and not only as an industrial system as for EMF). It expresses an economic system, in fact, based on business models that replace the concept of "end of life", with the reduction and, alternatively, with the reuse, recycling and recovery of materials in production/distribution and consumption processes. This can be done by operating at the micro (products, businesses and consumers), meso (districts and clusters supporting industrial symbiosis), and macro (cities, regions, nations and beyond) levels. The goal is to achieve sustainable development, which involves creating environmental quality, economic prosperity and social equity, for the benefit of current and future generations. [11]

The definition of EMF is the most accredited and often cited as a reference. The definition of circularity is based on the principles of Cradle to Cradle and System thinking and refers to two streams of materials: biological that return to the biosphere as possible nutrients, technical ones that cannot biodegrade and enter the biosphere. In this perspective, the approach highlights how the CE is able to maintain the value of these material flows over time as well as their usefulness, supported by appropriate design, management and technological innovation.

The most cited model within the EC is the one illustrated by the "butterfly" diagram introduced by the Ellen MacArthur Foundation in 2013.[12]

[9] Ellen McArthur Foundation 2013.
[10] Preston (2012).
[11] Please refer to the work of Ekins et al. (2019) and Frey et al. (2020) for further insights and definitions of the concept of circular economy.
[12] Source: EMAF (2013): https://ellenmacarthurfoundation.org/circular-economy

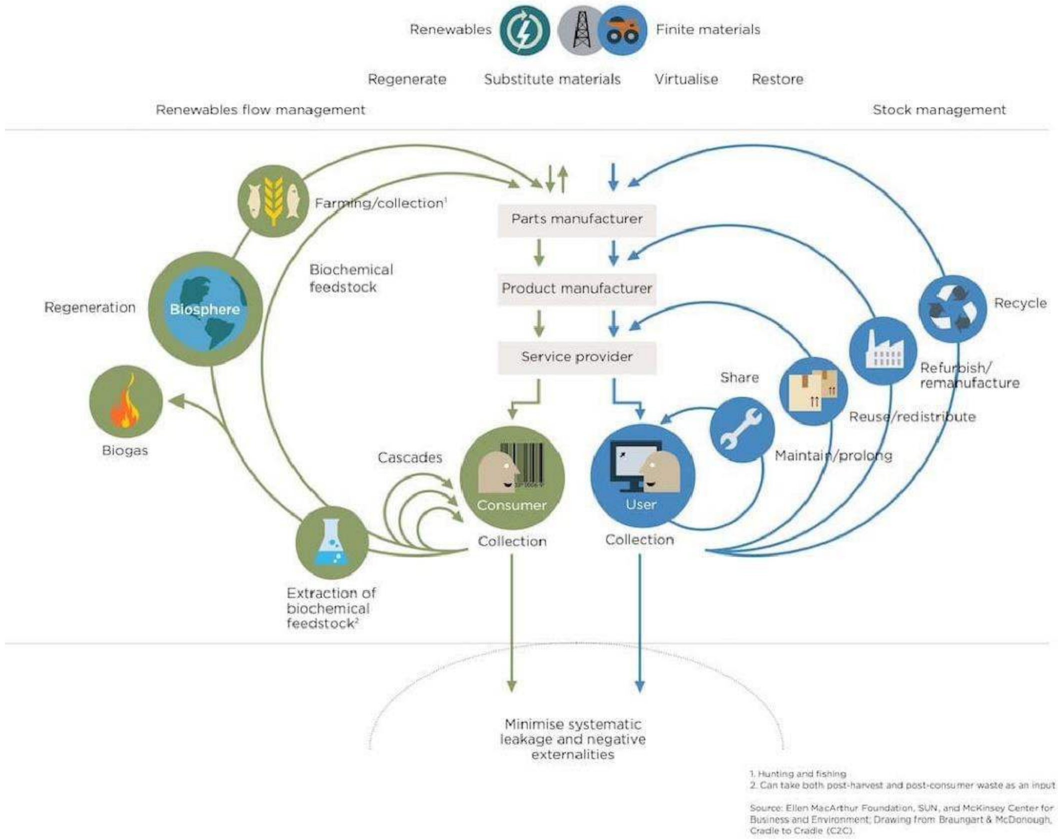

Figure 3: the butterfly diagram

The diagram illustrates the continuous flow of materials in a circular economy. There are two main cycles: the technical cycle and the biological cycle. In the technical cycle, products and materials are kept in circulation through processes such as reuse, repair, remanufacturing and recycling. In the biological cycle, nutrients from biodegradable materials are returned to the Earth to regenerate nature.

The fundamental principles and characteristics of a circular economy are drivers that allow four sources of value creation to be defined.

The first source, according to the considerations of Webster (2015), considers the individual circles of the diagram to be effective from different points of view. The effectiveness of the inner circle refers to the idea that the narrower the circle, the more valuable the strategy. Repairing and maintaining a product, such as a car, preserves most of its value. If this is no longer possible, the individual components could be reused or regenerated. This preserves more value than simply recycling materials. Inner rims better preserve integrity, complexity, and the work and energy embedded in a product.

The second source of value creation refers to the power associated with longer cycles, maximizing the number of consecutive cycles and/or time in each cycle for products (e.g. reusing a product several times or extending the life of the product). Each extended cycle avoids material, energy, and labor to create a new product or component. For energy-using products, however, the optimal service life must take into account the improvement in energy performance over time.

The third source refers to the strength resulting from cascading use and refers to the diversification of reuse along the value chain, for example when cotton clothing is reused first as second-hand clothing, then crosses the furniture industry as fiber filling in upholstery, and fiberfill is subsequently reused in stone wool insulation for construction – replacing an influx of virgin materials into the economy in any case - before cotton fibers are safely returned to the biosphere.

Finally, the effectiveness connected to pure inputs lies in the fact that flows of pristine materials increase the efficiency of collection and redistribution while maintaining quality, especially of technical materials, which in turn extends the longevity of the product and therefore increases the productivity of materials.

1.4. CE principles: definitions and application for firms

Starting from rather differentiated definitions in the literature, it is useful to deepen the theme of the principles on which the CE is based, necessary to define inspiring and operational schemes on which companies can then make circular choices and strategies.

At the heart of the evolution of the CE are the principles of the so-called 3Rs:

1. R1: **Reduction** of resource consumption and reduction of waste production and emissions associated with the production, distribution, and consumption process. For manufacturers, this principle is expressed in their pre-market role related to conceptualization and product design using fewer materials and resources or in the process of dematerialization.
2. R2: **Reuse** of waste and products, even after repair, or as components, in whole or partly for other products. Generally, the concept of reuse refers to a product in the second phase of consumption that needs minimal adjustments and that works as if it were new to perform the same purpose without being subjected to refurbishment or remanufacturing and, in any case, without being placed for repair activities. This category includes the

multiple use of packaging or products that are unsold or whose packaging has been damaged.

3. R3: **Recycling** of waste produced for reuse as a secondary raw material. In the hierarchical scale it is in third place when alternatives such as reduction, reuse, repair and remanufacturing are no longer feasible. Recycling may require the use of advanced and expensive technologies. The production of the secondary raw material does not maintain the characteristics of the original structure of the product except that the recycled material can be drawn and reused for new purposes.

To these first three Rs a fourth one relating to forms of recovery was added:

1. R4: **Recovery,** a concept that includes multiple situations. It concerns the collection of used products at the end of their life, their disassembly, selection, cleaning for their use. It can refer to the extraction of certain materials or elements from end-of-life products. It concerns the recovery of energy from waste or biomass use.

It is easily to assess that at European level, the EU waste hierarchy focuses exactly on the 4Rs, as listed above.

A more complete elaboration is that by Kirchherr et al. (2017) which sees additional 7Rs to be considered:

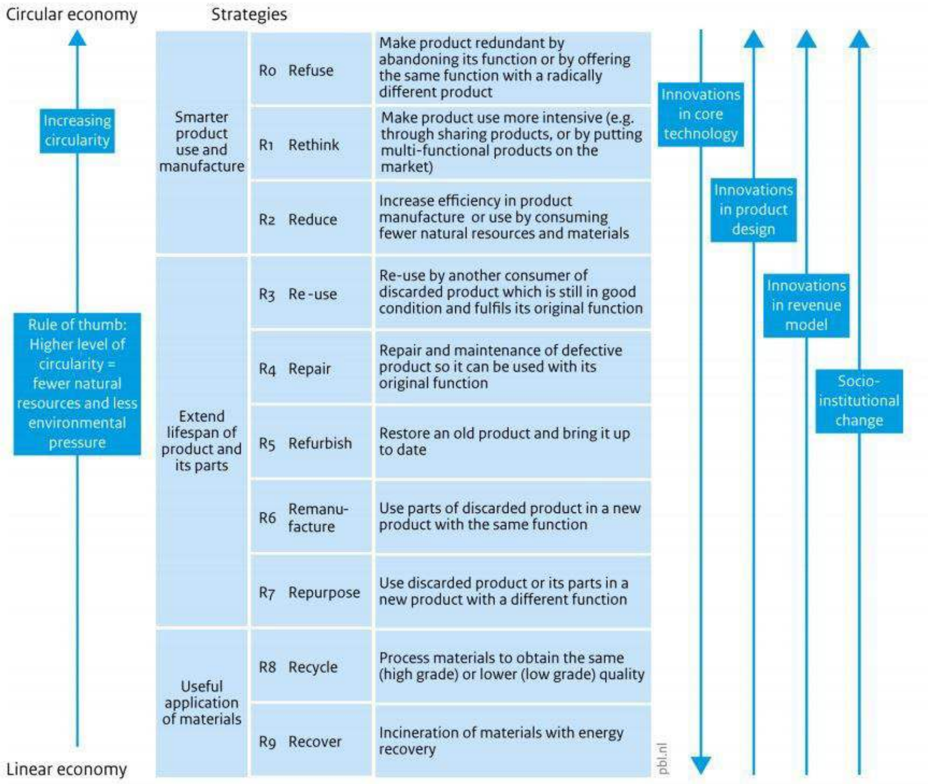

Figure 4: the Rs' strategies Source: ***Kirchherr et al. (2017)***

1. **Refuse**refers to the possibility of reducing and eliminating unnecessary products. In the case of companies, it is a question of eliminating the use of hazardous materials and substances and of conceiving the design of production processes aimed at reducing waste production and minimising the use of raw materials.
2. **Rethink -** rethinking the possibilities of making the use of products more intensively (sharing product) or multifunctional.
3. **Repair,** refers to the action of repairing and maintaining defective products so that they can continue to be used while maintaining their original function. The main purpose is to extend the life of the products, bringing back the original functions after the repair of minor defects, such as the replacement of parts or components that no longer work.
4. **Refurbish,** is the ability to **-** restore an obsolete product bringing it to the level of the most up-to-date ones. It includes actions by which the overall structure of multicomponent products remains intact, while some of these are replaced or repaired obtaining an upgraded product. Process feasible on buildings or on means of transport, excavators, motions, machinery.

5. **Remanufacture,** referring to the use of waste products or their parts and components for use in new products having the same function. It can also include activities such as reconditioning, reprocessing or restoration. This operation is carried out through disassembly, control and verification, cleaning and, if necessary, replacement or repair in an industrial process. A more nuanced concept than the Refurbish and where the product is as new or brought back to its current state, it uses recycled components but with a shorter residual useful life.
6. **Repurpose,** referring to the **-** use of waste products or parts thereof within new products with different functions.
7. **Re-mine** (not included in the 10 R) refers to the recovery of materials taken from landfills. Consider, for example, the enormous amount of metals present in landfills and whose selection could allow use as a material in production processes.

Of all these principles, it can be said, some fall more within the scope of consumer activities (refuse, reduce, reuse, repair) while others are more relevant to production companies (refurbish, remanufacture, repurpose). The remaining principles refer instead to the processing of aggregate flows of materials often associated with forms of downgrading of the value of resources (recycle, recover, re-mine).

The study of CE principles is fundamental, but this must be accompanied by appropriate actions to make them effective. In this regard, the study by Suárez-Eiroa et al. (2019) highlights some principles underlying appropriate actions:

1. adjust inputs to the system to regeneration rates (distinguishes between renewable and non-renewable resources);
2. adjust the outputs from the system to the absorption rates (distinguishes between technological and biological outputs);
3. close the system (link the waste management phase with the raw materials acquisition phase);
4. maintain the value of resources within the system (durability and recirculation of resources through the different phases of the product life cycle);
5. reduce the size of the system (reduce the amount of products needed to meet human needs, produce and consume more sustainable products);
6. designing for CE (design of products to be recycled and recovered, eco-design);

7. educate for CE.

Important is, in particular, the last of the principles indicated that concerns, on the part of manufacturers, the launch of strategies on the CE that require to integrate values, knowledge and skills. As the CE does not intend to evaluate the life cycle of products to demonstrate a reduced environmental impact but aspires to evaluate individual products in a holistic vision in which the product moves by exploiting different connections between different processes. Such an approach requires a real paradigm shift aimed at involving and connecting all social actors in order to foster collaboration. This is because the design of a product according to systemic and holistic logic with other companies requires undoubted individual and social skills that must be improved.

1.5. The concept of circular value chain

The analysis is deepened here with a specific reference to the theory of the value chain. This is done in order to highlight how the flow of materials, information, capital and relationships are able to generate value at an economic, social and environmental level characterizing the supply chain as sustainable and circular. The value chain will be evaluated by identifying the nodes on which it is composed to understand how each of them, applying the principles of the 10Rs, contribute to creating circular value.

The book "Competitive Advantage" by Michael Porter (Porter, 2008) defines the value chain as a set of activities to create value for customers, gain a competitive advantage (Porter, 1985) and, finally, achieve economic success. Value chain analysis aims to consider and control cost factors related to economies of scale, learning and its impact, capacity utilization model, linkages, interrelationships, integration, timing, organisational policies and location. This concept takes into account cost minimization, differentiation for obtaining competitive advantage. All aspects related to the product and supply chain management in a linear perspective.

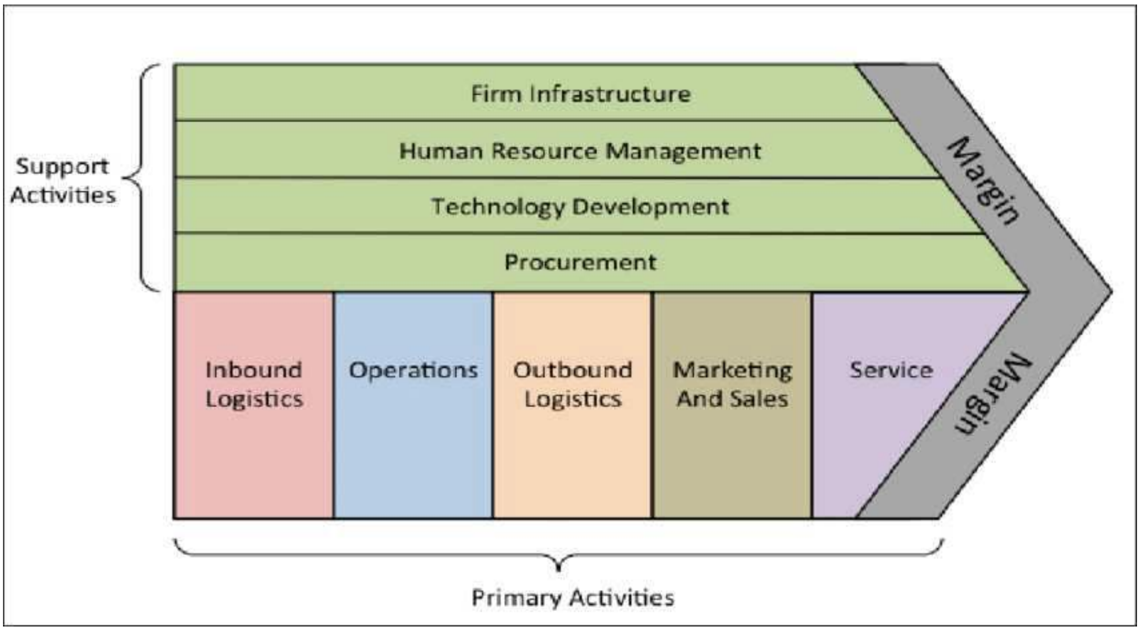

Figure 5: the linear value chain

In the linear system, the so-called primary activities within the value chain are related to inbound and outbound logistics and ignores reverse logistics. Furthermore, the support activities refer only to the creation of value in the organization without considering the creation of social and environmental value as well as aspects related to sustainability.

The sustainable value chain considers, more broadly, the entire production process that consists of product development and the processes of an organization's supply chain. It covers all stages of the life cycle from the idea/concept, to raw material sourcing, production and distribution, and use by end customers to the point where the product returns to a biological or technical cycle, thus closing the cycle (D'heur, 2015).

The circular value chain, therefore, analyzes the system from a holistic point of view and aims to achieve organizational, social and, of course, environmental objectives. It can be defined as a process and set of activities through which an organization maintains and regenerates value using secondary raw materials, through reverse logistics. In addition, it aims to create regenerative value by practicing sustainable actions in support activities by acting on human resources, procurement, technology and its infrastructures of which the company is composed. In this context, all functions and activities that contribute to creating circular value are important. Moreover, unlike the linear chain, consumption and the role of the final consumer are also important aspects to consider in order to better implement reverse logistics.

In this context, therefore, it is important to apply the principles of circularity (from R0 to R9) in the value chain obtaining a circular value chain. The main reference concerns the innovative capacity, expressed by the Refuse Rethink Reduce principles (R0, R1 and R2), applied to each phase of the value chain while the remaining principles are applicable only to some phases[13].

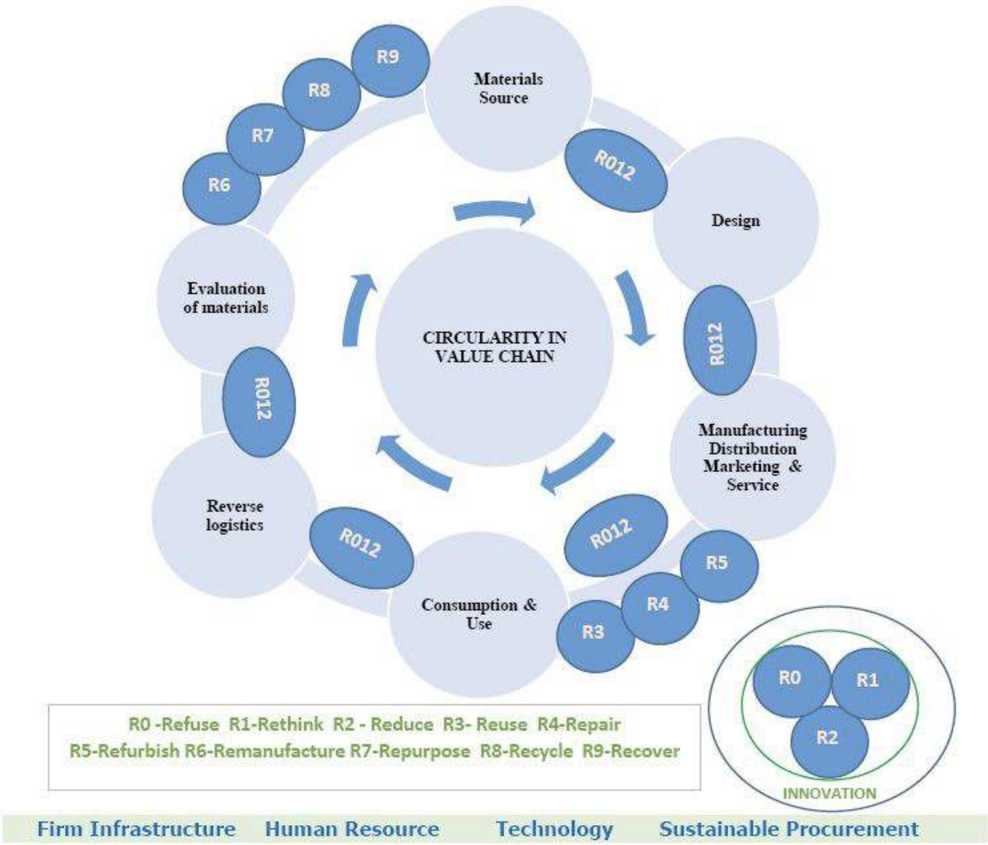

Figure 6: the circular value chain

In the first phase of the value chain, evaluation of materials, the reference principles are related to all those processes capable of transforming second raw materials into finished products. Principles R6 to R9 provide this opportunity to treat parts of products destined for waste to obtain new opportunities for use including incineration. In this case, the greatest added value can be obtained from these new applications of the product at the end of its life, which feed the Material Source, without affecting new natural resources. Also, in this context it is important to consider the industrial symbiosis system to optimize the use between companies of materials considered waste or by product.

[13] Graphic taken from Shaharia (2018).

In the next phase, products resulting from waste selection or by-product processes must be evaluated and designed for new uses through product design innovation to meet new needs in a circular perspective.

This is followed by the phases concerning production, distribution, marketing and services, upstream of the consumption or use of products. In this context, the innovative approach concerns aspects relevant to production activity with regard to energy efficiency, productivity in the use of materials and flexibility. Logistics is an important phase both for the entry of materials into the production process and for what concerns the output. Downstream there is the consumption process that must be supported by increased awareness on the part of the end customer, reducing the knowledge gap on products and applying product innovations. The principles from R3 to R5 support circularity in consumption and uses, allowing the extension of the life of the product or intensifying circular cycles. The last phase of closure of the circle is given by the Reverse Logistic downstream of the consumption activity that allows to reuse the materials as inputs for new applications.

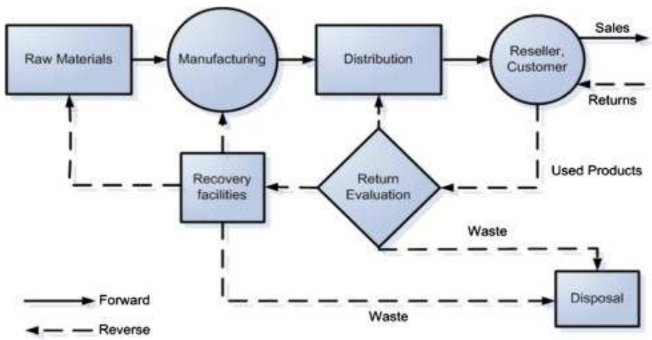

Figure 7: forward and reverse cycles

1.6. The application of the principles in the business context

The theoretical framework developed in the previous paragraphs has identified a series of guiding principles for CE orientation. These principles were tested developed and defined by Frey *et al.* (2020) within research projects that have seen the involvement of numerous experts and company managers. In light of these comparisons, six key principles have been identified to guide managers towards circular solutions. The principles identified are as follows:

1. **Reduce**: Managers must maximize efficiency, productivity and the degree of resource utilization. In this context, the dematerialization and use of renewable resources, secondary raw materials and by-products is advocated. This principle is supported by

closed cycles. Industrial symbiosis is seen as a fundamental strategy for reducing resource use. In addition, a strong stakeholder involvement is required within the different networks in which the company is involved, through close forms of collaboration. Crucial, therefore, are the quality of the network as well as the nature and strength of the links between the stakeholders.

2. **Regenerate**: need to improve a system, an area, a place to make it more functional, stimulate its positive capabilities. It implies the adoption of a holistic and systemic vision that considers all types of capital existing in a context: natural, social, economic, built, human. This approach implies the need to create shared value, setting regeneration targets for all types of capital considered. It is necessary to work on capital flows and assets, enhancing the set of relationships. Thus, for example, the focus on natural capital consists in determining positive impacts on the environment, of a biotic and abiotic nature, capable of improving its functioning, resilience, the generation of ecosystem services. In this context, it is necessary to define a complex governance structure capable of supporting the well-being of humans, individuals and their local communities. The role of managers, therefore, is to conceive business as an integral part of a complex ecological and socio-economic system.
3. **Rethink**: the principle implies the rejection of the linear approach by managers focusing on design and considering the entire product life cycle. Be aware of the impacts that decisions can have on resource flows and their stocks. Therefore, take responsible decisions by the actors concerned on the basis of information made available. In this context, companies implement appropriate accountability and carry out activities in a transparent manner, based on information made available on products and processes, favoring circular choices on their interlocutors and consumers. New digital technologies, big data, IoT can support this principle. As well as servitization, co-creation, co-management, sharing, mass customization are useful activities to change the current way of thinking.
4. **Innovate**: the principle of innovation requires managers to find new solutions through technologies, organization management, nature and composition of the materials used, product design, services, operational processes. It also implies the capacity for social innovation in outlining new solutions that meet a need and determine new relationships,

capabilities, use of goods and resources. It consists in improving the overall social capacity to act. It implies collaboration between all actors, internal and external to the company.

5. **Revalue**: refers to the ability of managers to maintain the value of resources and products unchanged over time. An organization's upcycling capability must be improved, that is, increasing the quality or value of a material, resource, product, or component. This activity can be implemented through actions such as maintenance and repair, reuse, repurpose, refurbish, remanufacturing, refitting, renovation, reconversion, recycle, recovery, remine. Also in this case symbiosis, closed cycles, servitization, reverse logistics contribute to reinforce this principle.
6. **Collaborate**: Managers must develop forms of collaboration inside and outside the company by leveraging their networks. CE principles must help substantiate relationships in these networks. Collaboration is essential to implement the previous principles through forms of training, communication, awareness, which managers must be able to implement to increase awareness on CE issues. Collaborative work, sharing, co-creation, mass customization are all activities that derive from forms of collaboration.

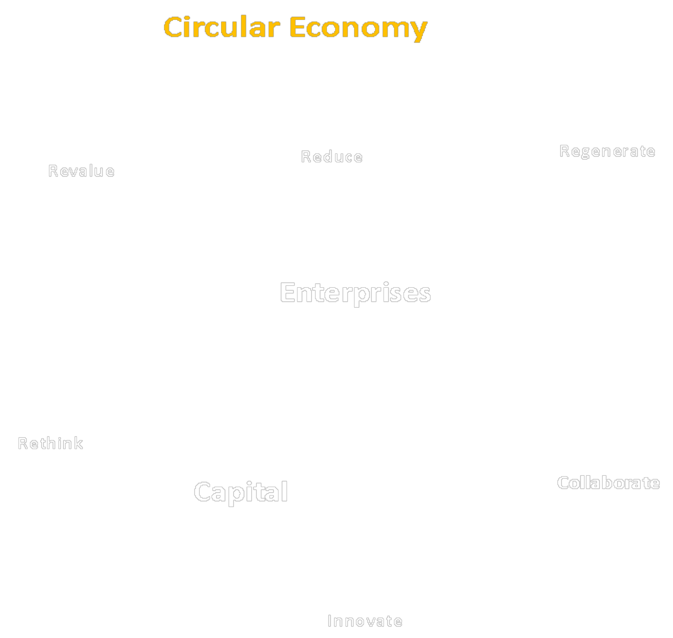

Figure 8: Rs' principle and main orbits

The conceptual model discussed above highlights a broader spectrum of evaluation that must be considered within companies when approaching the circular economy.

More specific, however, are the actions identified by the EMF always downstream of a process of involvement of companies and interviews with experts[14]. Also in this case, a set of six specific actions has been identified that managers and governments must consider to support a transition process towards the circular economy: the ReSOLVE model.

[14] Sulla base dello studio del 2016 di McKinsey intitolato "The circular economy: moving from theory to practice".

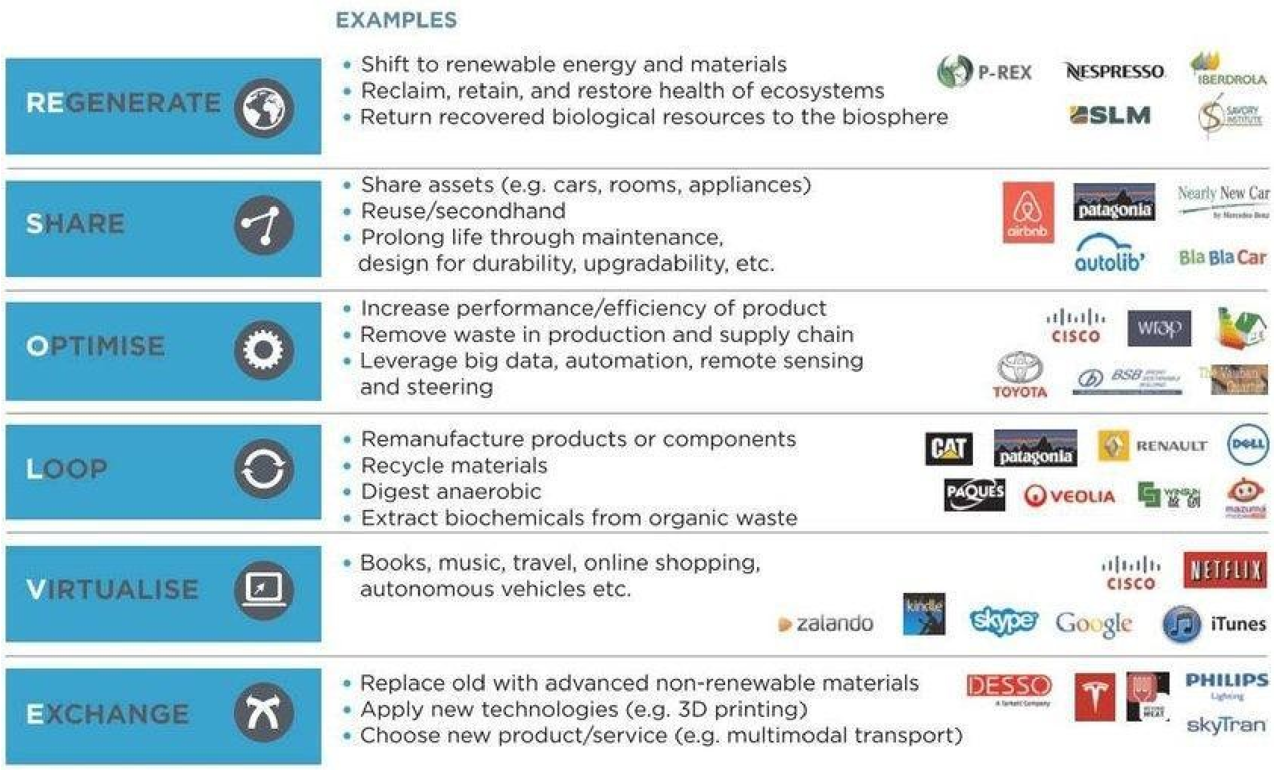

Figure 9: the ReSOLVE scheme

The ReSOLVE scheme is an important tool for businesses and governments to develop circular strategies and growth processes. Each for its part, all these actions make it possible to increase the use of physical resources, prolong their life by moving towards renewable sources. Each action reinforces and accelerates the execution of the other actions. Finally, alongside each action, the brands of companies that have stood out for circular economy activities are indicated.

Recently published is the decalogue by Velenturf and Purnell (2021) that propose a scheme of values and identify a set of principles for the design, implementation and evaluation of a sustainable path towards the circular economy:

. Manifesto for a Sustainable Circular Society.

Value framework:

Sustainable circular society: An equitable society that maintains environmental quality and economic prosperity for current and future generations:
A Social and individual well-being: Create conditions that offer equity in realising quality of life that at least meets human rights standards for all.
B Environmental quality: Using resources within planetary boundaries, enhancing natural capital within and across generations.
C Economic prosperity: Collective organisation of fair access to resources within and across generations to enable social and individual well-being and enhance environmental quality.

Principles:

1 Beneficial reciprocal flows of resources between nature and society: Society is an open system embedded in the biophysical environment for their mutual sustainable co-existence. Reciprocal flows of materials both extract from and add value to natural capital, with rates of resource extraction and return to environment lower than the regenerative and absorptive capacity of the Earth.
2 Reduce and decouple resource use: Promote resource sufficiency, efficiency and dematerialisation through governance that decouples progress from unsustainable material use.
3 Design for circularity: Design, select and transform industrial systems, supply chains, materials and products, using "R-ladders" and whole-system assessments of solutions to optimise stocks and the degree of closing loops of resource flows, minimising raw material extraction and waste generation, optimising value generated for people, and enabling reintegration of materials into natural biogeochemical processes at end-of-use, through continuous processes nurturing sustainable solutions, through innovation, and phasing out unsustainable practices, through exnovation, to implement and maintain a sustainable circular society.
4 Circular business models to integrate multi-dimensional value: Develop innovative business models and accompanying governance frameworks to internalise social and environmental costs of materials and products into their prices and reward circular practices more than resource intensive practices to enable the optimisation of resource values.
5 Transform consumption: Move away from producer-driven consumerism and towards systems-of-provision that enable responsible, reduced, demand-driven resource use and more sharing, service and experience-based consumption.
6 Citizen participation in sustainable transitions: Enable participatory systems to involve citizens in social innovations driven by transformative resource use, connecting grass root initiatives, ideas and opinions to local, national and supranational policy development and decision-making.
7 Coordinated participatory and multi-level change: Coordinate the development, integration and implementation of circular economy strategies and actions across societal actors – incl. government, industry, civic sector, consumers and academia – and across local to global scales, identifying key intervention points where the dedication of resources such as investment, policy change and expertise offers the most benefits for realising a circular economy.
8 Mobilise diversity to develop a plurality of circular economy solutions: Promote a plurality of perspectives and solutions for circular economy and a culture of knowledge exchange and learning across society, to generate a global knowledge base in support of local, context-dependent implementation, to build-in resilience against uncertainty that accompanies transition processes with sufficient back-up solutions, and to adopt a precautionary approach for solutions that may not be as sustainable as envisioned.
9 Political economy for multi-dimensional prosperity: Embed strong sustainability in political-economic systems, moving from a narrow focus on short-term economic progress i.e. GDP growth to long-term multi-dimensional prosperity in environmental, social and economic terms.
10 Whole system assessment: Take a whole system approach to understand challenges and the potential of proposed solutions in a precautionary manner, and optimise material use within the value framework for a sustainable circular economy through a process of continuous improvement guided by whole system assessments using holistic indicators before, during and after the implementation of circular economy practices.

Figure 10: Manifesto per Sustainable Circular Society Source: Velenturf A. and Purnell P.

As for the principles (Manifesto for a Sustainable Circular Society) many are, of course, coinciding with the previous models, partly analyzed in this paper. For the strengthening and development of industrial parks in a sustainable perspective, the principles between 7 and 10 are very important.

The development of circularity and the potential offered in the context of the establishment of Eco Industrial Parks can be highlighted with material principles, linked to the use of material and physical resources (secondary raw materials, waste, by-products, water, energy, etc.), to the possibility of creating solutions of industrial symbiosis between companies belonging to the same territorial context. However, this is not enough. It is also necessary to strengthen the system of relationships that allow the development of a coordinated system of participation at multiple levels of society: inclusion of government, industry, civil sector, consumers. In the context of industrial parks, this participatory process is essential to consolidate the link between companies, involve citizens in the development process on the territory, who must see the park as an opportunity for economic, social and environmental development. In addition, the involvement of the local government is very important, not only for the phase of permits for production activities but able to integrate industrial activity within a development path and possibly regeneration of the reference territory.

Circular development also requires the definition of different development perspectives as well as solutions to be implemented in order to increase knowledge, exchange and learning. This is in order to consolidate the participation of the local context in the development process inherent a path to circularity, also at the level of the industrial park, and consolidate resilience against the uncertainty deriving from the necessary transition to more circular and sustainable models. Finally, a circular process must necessarily have a systemic approach able to consider all the relationships with the main stakeholders that in various ways can improve the development process and strengthening, for example, an Eco Industrial Park. The set of indicators aimed at measuring circularity (analyzed in the following paragraphs), therefore, must be conceived in a holistic and inclusive perspective on the complex system of relationships that binds a subject, such as an industrial park, with all the main stakeholders of reference.

1.7. European policies on the EC

CE implementation in the European policies has emerged mainly through regulations closely related to waste and its recycling in the continent's economic systems. As the concept has recently broadened, the EU approach has also shifted more and more towards concepts of resource efficiency, closing cycles and a systemic consideration of all stages of the supply chain (procurement, design, production, distribution, use and end-of-life). In 2014, the European Commission published the Communication "Towards a circular economy: a programme for a zero waste Europe" aimed at outlining a strategic, common and coherent framework for strengthening actions towards circularity. In 2015, precisely in this perspective, the European Commission published the "Circular Economy Package" containing a set of policy measures aimed at orienting and promoting the economic and social system towards shared objectives of circularity. [15][16][17]

In 2018, the four new circular directives are published, introducing clear targets for reducing waste generation and recycling[18]. Also in that year, the European Strategy for Plastics in the Circular

[15] Analysis conducted by NGOs such as the Ellen McArthur Foundation, Circle Economy, and the Institut de l'economie circulaire.

[16] COM (2014) 398, Towards a circular economy: A zero-waste programme for Europe, Brussels, 2 July 2014.

[17] COM (2015) 614, The missing link- EU Action Plan for the Circular Economy, Brussels, 2 December 2015: SWD (2015) 260, Commission Staff Document, Implementation Plan, Brussels, 2 December 2015.

[18] Directive (EU) 2018/849 of the European Parliament and of the Council of 30 May 2018 amending Directives 2000/53/EC on end-of-life vehicles, 2006/66/EC on batteries and accumulators and waste batteries and

Economy was published, indicating the process of transforming the way plastics and products are designed, produced, used and recycled[19]. The strategy sets 2030 as a target for recycling all plastic packaging.

In 2020, the European Commission published the new action plan for the circular economy, which is[20] one of the main cornerstones on which the European Green Deal is based.

The European strategy is now very focused on the system thinking approach and on the importance of design derived from the analysis of Performance Economics and Cradle to Cradle. This approach was influential on the definition provided by the European Commission (EC, 2015) which, precisely in the Action Plan for the circular economy, identifies a series of measures to support the entire product cycle. Starting from production to consumption, to waste management, to the market of secondary raw materials, showing a change compared to the traditional waste policy that was very oriented to the end of life, i.e. the treatment and management of materials and products that have become waste.

In particular, in the Directive 2008/98 / EC, Article 4, [21]it is clear the analogy with the principles of 4Rs, providing for a hierarchy of priorities in the field of waste prevention and management:

1. prevention;
2. preparation for reuse;
3. recycling
4. Other recovery (energy)
5. disposal.

accumulators, and 2012/19/EU on waste electrical and electronic equipment; Directive (EU) 2018/850 of the European Parliament and of the Council of 30 May 2018 amending Directive 1999/31/EC on the landfill of waste; Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018 amending Directive 2008/98/EC on waste; Directive (EU) 2018/852 of the European Parliament and of the Council of 30 May 2018 amending Directive 94/62/EC on packaging and packaging waste.

[19] European Commission, (2018), European Strategy for Plastics in a Circular Economy, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM (2018) 28 final, Brussels.

[20] European Commission (2020), A new action plan for the circular economy For a cleaner and more competitive Europe, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM (2020) 98 final, Brussels.

[21] As also reiterated in the context of the European Circular Economy Strategy COM/2015/0614.

Member States apply the hierarchy by trying to choose the options that can give the best possible result in environmental terms.[22]

2. Application of circular economy principles to industrial sectors and sites. The Eco Industrial Parks

The application of the principles of the circular economy to industrial parks is very important for all the considerations made in the previous paragraphs and concerning the rational use of resources and the application of circularity principles. Mainly the areas of attention concern the exploitation of water resources and related discharges, energy supply and the use of renewable sources, the containment of waste production and its management.

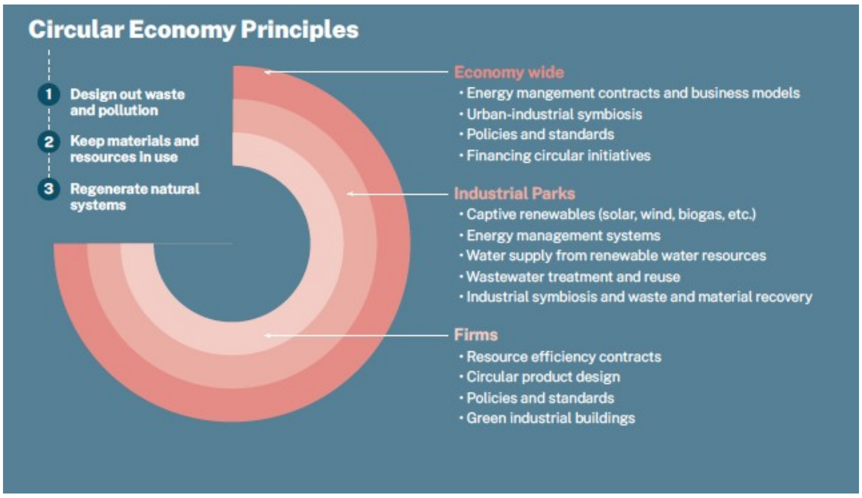

Figure 11: EIPs and circular principles- Source: World Bank

To make circular actions effective within companies and in industrial parks, however, innovative approaches are needed for the application of new technologies and the adoption of revised business models. The sustainable path of an industrial park requires a series of useful strategies to develop the circular economy. Below is proposed an analysis that takes into account some principles of circularity carried out in the previous paragraph.

Strategies for developing the CE	Principle	Source
Promoting higher renewable energy generation and use, and achieving	Reduce	Frey et al (2020)
	Regenerate	EMF-ReSOLVE

[22] This means that it may be necessary for some types of waste to deviate from the hierarchy if justified in terms of life cycle and considering the overall impacts of the production and management of such waste.

carbon neutrality	Mobilise diversity to develop a plurality of circular economy solutions	Velenturf e Purnell (2021)
Investing in common infrastructure and service provision to optimize the use of resources (e.g., steam networks, CO2 recovery plants, cogeneration/ trigeneration using biomass and/or biogas)	Reduce, Innovate	Frey et al (2020)
	Share, Optimise	EMF-ReSOLVE
	Mobilise diversity to develop a plurality of circular economy solutions	Velenturf e Purnell (2021)
Keeping materials and resources in use at the park level by encouraging tenant firms to create a symbiotic network and enabling their waste and by-product exchange	Revalue, Innovate, Collaborate	Frey et al (2020)
	Share, Loop	EMF-ReSOLVE
	Reduce and decouple resource use	Velenturf e Purnell (2021)
	Mobilise diversity to develop a plurality of circular economy solutions	Velenturf e Purnell (2021)
Designing waste out by encouraging tenant firms to integrate circular designs and to use environmentally friendly technologies in their production facilities	Rethink, Innovate	Frey et al (2020)
	Exchange, Optimise	EMF-ReSOLVE
	Design for circularity	Velenturf e Purnell (2021)
	Mobilise diversity to develop a plurality of circular economy solutions	Velenturf e Purnell (2021)
Fostering the establishment of recycling enterprises and sorting facilities rendering services to tenant firms	Reduce, Rethink, Innovate, Revalue, Collaborate, Regenerate	Frey et al (2020)
	Loop, Exchange	EMF-ReSOLVE
	Mobilise diversity to develop a plurality of circular economy solutions	Velenturf e Purnell (2021)

Rethinking business models for improved energy, water, and waste management at the park level	Rethink, Innovate	Frey et al (2020)
	Exchange	EMF-ReSOLVE
	Circular business model to integrate multi-dimensional value	Velenturf e Purnell (2021)
	Mobilise diversity to develop a plurality of circular economy solutions	Velenturf e Purnell (2021)
Harnessing digital technologies to increase resource circularity and material exchange	Reduce, Innovate, Rethink,	Frey et al (2020)
	Optimise, Virtualise	EMF-ReSOLVE
	Reduce and decouple resource use	Velenturf e Purnell (2021)
Establishing target and enforcing legally binding agreements between tenants of the EIP	Reduce, Collaborate	Frey et al (2020)
	Circular business model to integrate multi-dimensional value	Velenturf e Purnell (2021)
Create training opportunities on circularity issues to improve the technical skills of the personnel involved	Rethink, Innovate	Frey et al (2020)
Enforce relationships among tenants coordinating knowledge exchange, data collection and sharing, management; promoting trust and mediation for different interests and needs.	Reduce, Collaborate	Frey et al (2020)
	Circular business model to integrate multi-dimensional value	Velenturf e Purnell (2021)
Encouraging investments in common green infrastructure and enhancing access to collective financing	Reduce, Innovate, Collaborate	Frey et al (2020)

Developing R&D support in the EIP boundaries for all the involved firms	Reduce, Innovate, Collaborate	Frey et al (2020)
Presence of public sector to push toward circular economy Technologies-Public Private Partnerships-PPPs	Regenerate, Collaborate	Frey et al (2020)
	Political economy for multi-dimensional prosperity	Velenturf e Purnell (2021)
Integration of urban-industrial ecosystem to extend the boundaries of EIP	Reduce, Regenerate, Rethink, Innovate, Collaborate	Frey et al (2020)
	Mobilise diversity to develop a plurality of circular economy solutions	Velenturf e Purnell (2021)
Be active in enabling regulatory framework at local/regional level to sustain the adoption of circular solutions: more ad hoc regulation on EIPs, permitting, facilitation/incentives for firms entering the EIP	Regenerate, Collaborate	Frey et al (2020)
	Political economy for multi-dimensional prosperity	Velenturf e Purnell (2021)
Involvement of local communities in the process of enforcing the EIP; including local town in the service providing; support the local investment applying circular principle (i.e nature based solutions); support the regeneration of local areas/communities	Regenerate, Collaborate	Frey et al (2020)
	Beneficial reciprocal flows of resources between nature and society	Velenturf e Purnell (2021)
	Citizens participation in sustainable transition	Velenturf e Purnell (2021)
Enforce collaboration to create joint values with key stakeholders: tenants firms, industrial associations, local suppliers, infrastructure operators, regional/local governments, service and technology providers, financial actors.	Collaborate	Frey et al (2020)
	Citizens participation in sustainable transition	Velenturf e Purnell (2021)
	Political economy for multi-dimensional prosperity	Velenturf e Purnell (2021)

Table 1: Strategies and principles to develop CE - Source: our elaboration based on papers and Ecole-Pilot Group Fora exercise

The table above shows possible development strategies for the CE in industrial parks. The strategies see not only a close correlation with the most material and productive part of industrial processes. Such strategies shall need to apply a systemic approach that also takes into account relevant relationships with all stakeholders in the area. It is by considering such relationships that circularity is promoted and enforced on the territory.

The principles of circularity, according to different sources, cover, in several ways, all possible implementable strategies. Starting from these principles, and for each strategy, it will be possible to identify indicators for measuring the circularity performance of a company or group of companies. They must also make it possible to trace the development trajectory towards improvement of circularity performance on the basis of reference benchmarks or objectives that the organization aims to achieve.

2.1. Circularity measurement: introduction to metrics and KPIs

After investigating the different definitions and dealing with the general principles of inspiration and operation of circularity, it is necessary to understand how it is then possible to measure outcomes through the identification of specific indicators for circularity. The examination of the principles mentioned above has allowed us to outline a complete framework of knowledge on the issue of circularity, within which it is necessary to move to identify the indicators that in different ways and with different purposes prepare measurement models. Some principles, specifically those of the "R", constitute real operational indications aimed at pursuing the objectives of circularity with clarity and concreteness. Other principles refer mostly to the attitude necessary to drive the transformation towards the context of social sustainability. The "construction" of a performance indicator that has at its base an operating principle ("material") will be easier and more immediate than another that instead has at its base principles of inspiration (diversity, inclusiveness ...) aimed at promoting good practices and circular culture.

Let's start by saying that circularity measurement is a complex activity. As far as indicators are concerned, these are of different nature: some are dedicated to the measurement of individual products and services, others to entire organizations and still others to production processes; some indices are not characterized by being focused on a specific sector (and therefore can be applied in a transversal way), others are sectoral (and therefore have a value only in their own scope); some (most) have quantitative characteristics, others qualitative (susceptible to a subjective evaluation allowing, for example, to determine the progress with respect to an objective), others are hybrids (i.e. they have both a quantitative and qualitative component). Some indicators are physical, others economic, others organizational or social. There are also several possibilities for metrics: on specific aspects of the circular economy, on life cycle stages. Others allow to obtain the measurement with a synthetic index still others with a series of several indices. For some measurements, the output is numeric, or percentage or mix. In some cases, measurement models provide combinatorial logic, others do not.

The above has led to different measurement models applicable to different business realities. Here are some examples:

1. **Circulytics**: online tool for measuring the circularity of companies to support their transition to circularity. The tool measures the circularity of the organization as a whole and is therefore not focused on individual products or material flows.[23]
2. **Circular Transition Indicators (CTI)**: of the World Business Council for Sustainable Development, a framework that "is based on an assessment of material flows within company perimeters, combined with additional indicators on resource efficiency and effectiveness, as well as on the added value generated by the related business. The goal of using this framework is to provide companies with a tool that helps them acquire concrete information on the transition to a circular model and identify the opportunities associated with it.
3. **The Unido Eco Industrial Parks (EIP) Tools**: very important tool that includes several topics of interest for EIPs. It is based on the International Framework for Eco-Industrial Parks and aims to analyze in detail the activities related to the initiatives of industrial parks. It is composed of several tools each with specific monitoring objectives. For example, the Industrial Symbiosis Identification Tool aims to identify opportunities arising from industrial symbiosis and by-product and/or waste exchanges between companies. The tool can be used by companies already operating in a specific industrial park. It can also be used to test a new park and highlight the potential for industrial symbiosis between companies located in an area and which could give rise to an EIP[24]

[23] https://ellenmacarthurfoundation.org/resources/circulytics/overview.

[24]https://www.greenindustryplatform.org/tools-and-platforms/unidos-eco-industrial-parks-eip-tools-english

An important step following the identification of the principles, according to the different models identified, consists in identifying the areas of action that contribute to circularity for the individual companies that make up the IP (Circularity characterizing the single company) as well as identifying those areas of action that substantiate the existence of an EIP (Circularity for the entire EIP). Once the characterizing areas of action have been identified, it will be easier to identify the specific KPIs for measuring circularity. Below we try to carry out this exercise on the basis of the principles identified by Frey et al. (2020) identifying some areas of action for the identification of indicators:[25]

PRINCIPLE	Area of action single Enterprise	EIP Action Area
Reduce	● Renewable energy supply ● Renewable thermal supply ● Energy supply by symbiosis ● "Circular" water input ● Circular input for raw materials ● Circular Packaging ● Hazardous Waste ● …	● Rate of achievement of energy targets ● Rate of achievement of water targets ● Rate of achievement of waste reduction targets ● Optimization of incoming transport ● Intermodal Logistics ● Reducing emissions ● Waste reduction

[25] In fact, a further principle has been added to this table: Inclusiveness to take into account the degree of involvement of staff within companies, the well-being of local communities.

		● Water monitoring ● Supply chain carbon footprint
Rethink	● Circular Packaging ● LCA Studies	● Circular strategy ● Objectives on circular issues ● Natural capital pressure studies ● Insurance system ● Risk management system ● Risk mapping ● Environmental management systems ● Green finance
Innovate	● Product innovation ● Process innovation ● Digital innovation	● Joining Innovation Network ● Land monitoring systems
Revalue	● Water recovery ● Destination of waste ● Water recovery ● Circular design	● Energetic symbiosis ● Water recovery ● Destination of waste ● Information tools

		● Inbound reverse logistics
Collaborate		● Supply Chain Management Systems ● Involvement of actors for the mapping of risks and impacts ● Structure of collaboration between nodes ● Board di Supply Chain ● Contact with administrations ● Industrial symbiosis ● Joining a Network
Regenerate		● Participation in regeneration projects ● Support to industrial regeneration projects ● Regenerative cultivation
Inclusiveness	● Employee incentives on regeneration ● Circular Skills ● Internal training ● Behavioral innovation	● Well-being local communities ● Local suppliers

	● Change Management	

Table 2: Application of CE principles to single tenant firms and Industrial parks

Table 2 highlights, therefore, a dual application scheme for the measurement of circularity within industrial parks. A first set of indicators must be applied to the individual companies that make up the industrial park to highlight the circularity performance of each of them and allow to identify a reference benchmark. A second set of indicators has a transversal nature and involves all the companies belonging to the park. In addition, it must be able to assess the degree of relations between the park and all the stakeholders that interact with it and be able to support the circular development of production activities as a whole. Finally, these indicators must be able to evaluate the regenerative contribution on the reference territory to compensate for the presence on that territory and contribute to the preservation and growth of the natural assets present there.

In order to start thinking the model and KPIs developed in the following Actions of WP1 and referring to Table 2, we have tried to define some of the main indicators that could be used to measure circularity at single tenant firm and for EIP as a whole. Table 3, then, shows some example of possible KPIs to be applied at tenants' and Industrial Park as a whole.

INDICATOR ID	INDICATOR NAME	Question	Measurement Scale	Qualitative/Quantitative KPI	Inspirational KPI	Operative KPIs	Single firm/tenant	EIP as a whole
1	Renewable energy supply	**Percentage of electricity from renewable energy sources in the total electricity used.** Formula: [KWh of electricity supplied from renewable energy sources in the last 12 months / KWh of electricity consumed in the last 12 months]*100 Guide to calculating the indicator: Calculate the indicator at the level of the entire plant/production process.	[0 - 100%]	Quantitative		X	X	
2	Rate of achievement of energy objectives	**To what extent has the company achieved its objectives of reducing energy consumption due to efficiency measures within its factories/production lines/offices?** Refer to energy savings due to the replacement of machinery in the production process with machinery with more energy efficiency, the replacement of old generation bulbs with LED lamps, etc. Formula: [Recorded Energy Reduction / Energy Reduction Target]*100	[0 - 100%] [Not applicable, if no energy consumption reduction targets have been set]	Quantitative		X	X	
3	Energy supply by symbiosis	**Percentage of heat flow that is supplied by neighboring production companies with a view to industrial symbiosis.** Formula: [Heat flow supplied through industrial symbiosis activities in the last 12 months/Heat flux used in its production processes in the last 12 months]*100 Guide to calculating the indicator: Calculate the indicator at the level of the entire plant/production process.	[0 - 100%] [Not applicable, if no heat is used in its production process]	Quantitative		X		X
4	Outgoing energy symbiosis	**Percentage of the residual heat flow that is transferred to other neighboring production companies with a view to industrial symbiosis.** Formula: [Heat flow transferred to other subjects through industrial symbiosis activities in the last 12 months/Waste heat flux deriving from its production processes in the last 12 months]*100 Guide to calculating the indicator: Calculate the indicator at the level of the entire plant/production process.	[0 - 100%] [Not applicable, if no heat is used in its production process]	Quantitative		X		X
5	"Circular" water input	**Percentage of incoming water to the production process that is not taken directly from the water network but derives from internal reuse or recycling operations or from other organizations compared to the total water entering the production process.*** Formula: Volume of water procured by internal reuse or recycling operations or other organizations in the last 12 months/ Total volume of water procured for the product family under analysis in the last 12 months]*100 Guide to calculating the indicator: Calculate the indicator at the level of the entire plant/production process.	[0 - 100%]	Quantitative		X		X

Table 3: Example of KPIs- Quantitative, qualitative, for single tenant/Industrial Park

INDICATOR ID	INDICATOR NAME	Question	Measurement Scale	Qualitative/Quantitative KPI	Inspirational KPI	Operative KPIs	Single firm/tenant	EIP as a whole
1	Renewable energy supply	**Percentage of electricity from renewable energy sources in the total electricity used.** Formula: [KWh of electricity supplied from renewable energy sources in the last 12 months / KWh of electricity consumed in the last 12 months]*100 Guide to calculating the indicator: Calculate the indicator at the level of the entire plant/production process.	[0 - 100%]	Quantitative		x	x	
2	Rate of achievement of energy objectives	**To what extent has the company achieved its objectives of reducing energy consumption due to efficiency measures within its factories/production lines/offices?** Refer to energy savings due to the replacement of machinery in the production process with machinery with more energy efficiency, the replacement of old generation bulbs with LED lamps, etc. Formula: [Recorded Energy Reduction / Energy Reduction Target]*100	[0 - 100%] [Not applicable, if no energy consumption reduction targets have been set]	Quantitative		x	x	
3	Energy supply by symbiosis	**Percentage of heat flow that is supplied by neighboring production companies with a view to industrial symbiosis.** Formula: [Heat flow supplied through industrial symbiosis activities in the last 12 months/Heat flux used in its production processes in the last 12 months]*100 Guide to calculating the indicator: Calculate the indicator at the level of the entire plant/production process.	[0 - 100%] [Not applicable, if no heat is used in its production process]	Quantitative		x		x
4	Outgoing energy symbiosis	**Percentage of the residual heat flow that is transferred to other neighboring production companies with a view to industrial symbiosis.** Formula: [Heat flow transferred to other subjects through industrial symbiosis activities in the last 12 months/Waste heat flux deriving from its production processes in the last 12 months]*100 Guide to calculating the indicator: Calculate the indicator at the level of the entire plant/production process.	[0 - 100%] [Not applicable, if no heat is used in its production process]	Quantitative		x		x
5	"Circular" water input	**Percentage of incoming water to the production process that is not taken directly from the water network but derives from internal reuse or recycling operations or from other organizations compared to the total water entering the production process.*** Formula: Volume of water procured by internal reuse or recycling operations or other organizations in the last 12 months/ Total volume of water procured for the product family under analysis in the last 12 months]*100 Guide to calculating the indicator: Calculate the indicator at the level of the entire plant/production process.	[0 - 100%]	Quantitative		x		x
6	Rate of achievement of water targets	**To what extent has the company achieved its objectives of reducing water consumption in the production process due to efficiency measures?** Refer to the replacement of machinery in the production process with machinery of greater efficiency, the reduction of waste, etc. Formula: [Recorded water consumption reduction / Water consumption reduction target]*100	[0 - 100%] [Not applicable, if no water consumption reduction targets have been set]	Quantitative		x	x	
7	Output water symbiosis	**Percentage of process waste water that is sold to other neighboring production companies with a view to industrial symbiosis.** Think, for example, of the outgoing water symbiosis. Formula: [Volume of waste water from the production process sold to other companies in the last 12 months/ Total volume of waste water from the process in the last 12 months]*100 Guide to calculating the indicator: Calculate the indicator at the level of the entire plant/production process.	[0 - 100%]	Quantitative		x		x
8	Circular input for raw materials	**Percentage of materials used for the manufacture of the product that are procured as*:** A distinction is made between: • Consumed renewable raw materials (MMR): materials that by their intrinsic characteristic regenerate or are not "exhaustible" in the "human" time scale and, by extension, whose use does not affect natural resources for future generations. All renewable raw materials (including auxiliary ones) used in all industrial processes on the site must be considered; • Secondary raw materials consumed (MPS): materials deriving from waste recovery processes (they can either originate internally at the site or be supplied from outside). All secondary raw materials (including auxiliary ones) used in all industrial processes on the site must be considered; • By-products originated on the site and reused on the site (SI): by-products originated internally on the site and reused on the site; • By-products from industrial symbiosis and reused on site (SE): by-products supplied from outside and reused on site.	**The sum of the % must not exceed 100%**	**Quantitative**		x		
		- Non-renewable virgin raw materials [0-100]	[0 - 100%]				x	x
		- Renewable raw materials consumed [0-100]	[0 - 100%]				x	x
		- Secondary raw materials consumed [0-100]	[0 - 100%]				x	x
		- By-products originating on the site and reused on the site [0-100]	[0 - 100%]				x	x
		- By-products from industrial symbiosis and reused at the site [0-100]	[0 - 100%]					x
9	Circular strategy	**Has the company, as part of its business strategy, integrated the principles of Circular Economy*?** Refer, for example, to the explanation of the Circular Economy and its principles within the company's environmental policy documents and/or within the strategic policy and/or within its sustainability report or non-financial statement.	*A) There is no mention of the circular economy in the company's strategies.* *B) The company is integrating the circular economy as one of the strategic priorities.* *C) The circular economy is explicitly mentioned as one of the company's strategic priorities.* *D) The circular economy is explicitly mentioned as one of the strategic priorities of the company and eventual objectives defined have been shared with the other nodes of the supply chain.*	**Qualitative**	x		x	
10	Objectives on circular issues	**Have the company defined measurable objectives in relation to circular economy issues with respect to the areas listed below?** Answer for each of the topics listed.	**Yes,** measurable objectives have been defined. **No,** no measurable objectives have been defined.	**Qualitative**	x		x	
		- Efficient use of resources						
		- Innovation (Research , Patents, Social impact)						
		--Corporate Strategy (Strategic Supply Chain Plan)						
		- Collaboration (Number of meetings/events)						
		- Management of potential risks (Procurement, Climate)						
		- Others (please specify)						

Table 3: contd

11	Stakeholder mapping studies	**Does the company conduct stakeholder mapping studies aimed at obtaining a representation of all the actors that can influence its activities in the field of circular economy?** Refer, for example, to stakeholder mapping tools such as materiality analysis, Supply Chain Value Stream Mapping; supply chain network analysis; value network; Etc. Guide to the calculation of the indicator: This indicator should be considered in the light of the stakeholders involved in the supply chain of the production process under consideration. If this is not possible, please respond with reference to stakeholder analysis at company level.	*A) The company has not conducted stakeholder mapping studies. B) The company is implementing stakeholder mapping studies. C) The company has successfully carried out stakeholder mapping studies. D) The company has successfully carried out stakeholder mapping studies and has actively intervened by drawing ideas for improvement from the results.*	**Qualitative**	x		x	x
12	Adoption of digital toolsi	**Does the company adopt innovative tools of the digital transition of the supply chain for the purpose of collecting and managing data and sharing information?** Refer to Big Data Analysis, ITC Tools, and digital systems aimed at direct tracking along the chain of circularity information necessary for the realization of environmental impact studies and / or the adoption of the Digital Product Passport.	*A) No digital tools with such purposes have been adopted. B) The use of digital tools for this purpose is being implemented. C) Digital tools with these purposes have been successfully adopted within the company. D) Digital tools with these purposes have been successfully adopted also in collaboration with the other actors in the supply chain*	**Qualitative**		x	x	
13	Use of innovation tools	**Does the company, in programming and / or design activities, use innovation tools to encourage the adoption of circular practices?** Refer, for example, to Design Thinking, Visual Thinking, System Innovation, or the adoption of tools such as Canvas.	*A) The company has not adopted innovation tools for these purposes. B) The company is evaluating the possibility of using innovation tools for this purpose. C) The company is implementing innovation tools for this purpose. D) The adienda has successfully adopted innovation tools with these aims.*	**Qualitative**	x		x	
14	Adesione a network innovativi	**Does the company adhere to association mechanisms, networks, or multiskeholders platforms at national and international level, which actively carry out promotion and innovation activities for issues related to circularity and develop solutions for their dissemination?** Refer, for example, to joining Open Innovation networks or networks such as the World Business Council, UN Global Compact, Asvis' FuturaNetwork, etc.	*A) The company has not joined any network. B) The company has embarked on a path of joining a network. C) The company has successfully joined at least one network. (Please specify which one:__) D) The company has successfully joined networks and stimulates the nodes of its supply chain and / or the production companies close to undertake a similar path. (Please specify which one:__)*	**Qualitative**	x		x	x
15	Diversification of supplies	**Has the company adopted programs or policies to promote diversification within its supply chain for its product process under consideration?** Refer for example, to flexibility, multiple suppliers, nearshoring for categories of raw materials considered essential/strategic, etc. Guide to the calculation of the indicator: This indicator has to be considered by reference to the product family concerned.	*A) The company does not have programs or policies designed to promote diversification within its supply chain B) Programs or policies are being implemented to promote diversification within the company's supply chain C) The company has implemented programs or policies aimed at promoting diversification within its supply chain D) The company has implemented programs or policies aimed at promoting diversification within its supply chain by involving the actors in the supply chain.*	**Qualitative**		x	x	

Table 3: contd

16	Participation in regeneration projects	**The company, considering the last year of activity, has participated in the development of projects aimed at regenerating and increasing the quality of the territories in which it operates, using ecosystem based approaches* or other forms of industrial regeneration** ?** Refer, for example, to urban planning activities related to "Blue Infrastructures" (referring to city water areas, such as river banks, lake shores etc etc) and "Green Infrastructures" (referring to green areas such as parks, gardens, etc.). * An ecosystem-based approach refers to the integrated and comprehensive management of human activities based on the best available scientific knowledge on the ecosystem and its dynamics, in order to identify and act on influences that are critical to the health of ecosystems, thus achieving a sustainable use of ecosystem goods and services and maintaining ecosystem integrity". ** Refer, for example, to the reduction of the soil sealing layer with the aim of increasing water drainage, to the increase of green roofs (e.g. roofs or walls) with consequent benefits on the absorption of atmospheric CO2 and overall improvement of air quality thanks to the reduction of pollutants	*A) The company in the last year has not participated in projects related to this issue B) In the last year the company has started a process for the participation / promotion of projects related to this issue C) In the last year the company has participated in projects related to this issue D) In the last year the company has promoted and / or implemented projects related to this issue*	Qualitative		X		X
17	Projects towards the local community	**Considering the last year of activity, has the company participated in the development of projects to increase the well-being of the local community and the quality of the social fabric within which it operates?** Refer, for example, to charitable activities, creation of areas for recreational purposes, cultural and / or sports activities.	*A) The company in the last year has not participated in projects related to this issue B) In the last year the company has started a process for the participation / promotion of projects related to this issue C) In the last year the company has participated in projects related to this issue D) In the last year the company has promoted and / or implemented projects related to this issue*	Qualitative		X		X
18	Board di supply chain	**Is the company part of the supply chain board and actively participates in meetings organized between representatives of the actors in the supply chain?** Refer, for example, to the existence of a Supply Chain management aimed at managing transversal aspects to all actors in the supply chain such as risk management, sustainability / circularity or observation of changes in market demands.	*A) There is no supply chain board. B) There is no supply chain board but meetings are occasionally organized with representatives of some players in the supply chain. C) There is no supply chain board but meetings are occasionally organized with representatives of all the players in the supply chain. D) The supply chain has a formalized supply chain board and the company participates in meetings with representatives of the players in the supply chain, organized periodically and in a structured way.*	Qualitative		X		X
19	Contact with administrations	**Does the company interface with administrations/policy makers/regulators to promote the implementation of circularity solutions at system level?** Refer, for example, to advocacy strategies with policymakers related to specific needs of the company, such as the optimization of waste collection, the creation of consortium biodigestion or waste disposal plants, the creation of energy communities, as well as the implementation of rules to facilitate the spread of the circular economy.	*A) The company has not interfaced with administrations / polity makers / regulators. B) The company participates in events promoted by administrations / policy makers / regulators in the field of cicolare economy only when required to do so. C) The company actively interfaces with administrations/policy makers/regulators to promote circularity solutions D) The company actively interfaces with administrations/policy makers/regulators to promote circularity solutions by actively involving the other nodes of the supply chain.*	Qualitative	X			X
20	Alternative symbiosis programs	**Does the company carry out collaboration programs with nearby production companies and / or intermediaries in order to support the realization of industrial symbiosis activities alternative to the mere sharing of resource flows?** Reference, for example, to the sharing of utilities and / or infrastructures for the use and management of resources, to the joint provision of services to meet ancillary needs common to companies related to transport and / or waste management.	*A) The company has not activated collaborations for these purposes. B) The company is considering joining collaborative activities with these purposes with other nearby production companies and / or intermediaries (eg Symbiosis Incubators) or to promote them C) The company is promoting or has been involved in collaborative activities with these purposes with other nearby production companies and / or intermediaries (eg Incubators for Symbiosis) D) The company has successfully realized, and undertakes to maintain active, collaborations with other nearby production companies and / or intermediaries (eg Incubators for Symbiosis)*	Qualitative		X	X	X
21	Participation in networks	**Does the company adhere to association mechanisms, networks, or multiskeholders platforms at national or international level, which actively carry out activities to promote issues related to sustainability and / or circularity and develop solutions for their dissemination?** Refer to membership in networks such as World Business Council, UN Global Compact, Asvis FuturaNetwork, etc.	*A) The company has not joined any association / network. B) The company embarked on a path of joining an association / network. (Please specify which one:__) C) The company has successfully joined at least one association/network. (Please specify which one:__) D) The company has successfully joined more than one association / network and stimulates the nodes of its supply chain and / or the production companies close to undertake a similar path. (Specify at least two :__)*	Qualitative		X		X

Table 3: contd

The indicators listed in Table 3 are just some of the possible indicators applicable to industrial parks that we are going to analyze. Certainly, the type of indicators, as seen, is varied both in terms of measurability (operational or inspirational circularity), metric (quantitative or qualitative) and scope of application (single company and / or industrial park). Once the KPIs have been defined, these can be tested on the units of measurement and the relevant data and information collected. In terms of measurement results, it will then be necessary to define the combinatorial logics to obtain an overall "measurement" of circularity such that we will expect to obtain that the circularity relative to an industrial park is greater than the sum of the circularities of the individual companies that compose it.

3. The Alpine Space (AS) analysis on CE

In this section we consider the positioning and related documents that have been produced within the framework of the recognized European organizations for the enhancement of the Alpine territory.

In the first instance, it is interesting to refer to the Alpine Convention[26] which, through the Alpine System of objectives, has set itself 2050 climate targets, in line with European ones. In the document, although there are no aspects that specifically concern EIPs, however, there are some topics that relate to the circular economy regarding, for example, the efficient use of natural resources, the reduction in the exploitation of raw materials and renewable energy sources. In particular, in the 2020 document Green Economy in the Alpine Region[27] there is a specific focus on the circular economy and the presentation of some peculiar projects.

Within the EUSALP programme and strategies the different Action Groups (AG)[28] have developed analysis and papers dealing with circularity issues. None of these strategic documents would be directly connected to the theme of Industrial Parks and their transformation according to more sustainable and circular logics. However, the analysis presented in the documents deepens, in some cases, the logic of circular supply chains that can be identified at the level of the Alpine areas.

Concerning the main projects on circularity these include, for example, AlpLinkBioEco a project that develops a cross-regional, circular, bio-based, economic strategy and support the transition

[26] The Alpine Convention entails the guiding principles towards a sustainable life in the Alps https://www.alpconv.org/en/home/convention/framework-convention/

[27] https://www.alpconv.org/fileadmin/user_upload/Topics/Green_Economy_progress_report_2020.pdf

[28] To find more info on Eusalp AGs go to: https://www.alpine-region.eu/projects/circulalps-innovation-foster-sustainability-and-circular-economy-alpine-forestry-value

from a fossil-based economy[29]. The project's focus is on four sectors: agriculture, wood, chemicals and food/pharma packaging. For this objective, it connects diverse bio-feed-stock producers with intermediate product developers and end users of high value applications addressing critical societal needs. The project sets up a methodology to create new cross-regional value chains for a bio-based, circular economy, including a roadmap, demonstrations for intelligent assessments, selection and creation of innovative bio-based value chains (VC). The analysis covered in the AlpLinkBioEco Project shows that there is insufficient data to understand the impact of the bioeconomy in individual economies and Alpine macro-regions. However, the project itself has highlighted how this is a booming sector with the presence of regional assets and a strong development potential for cross-regional cooperation. This sector is certainly feasible for development also because the Alpine regions are rich in biomass and can count on numerous stakeholders to be involved in the transition process. In this context, the Ecole project would have the opportunity to exploit the potential of this sector not only to develop cross-regional synergies but also to encourage the creation of Eco industrial parks based on bio-based value chain to be strengthened on individual regional territories.

The Circulalps Project, [30][31]Innovation to foster sustainability and circular economy in Alpine Forestry Value Chain, for example, promotes the development of a circular and organic economy in the wood sector. A sector of strategic importance for the Alpine area also supported by innovative bio-based processes and in the field of circularity. A practical example of study analyzed by the Eusalp AG2 concerns the process of reuse of ash resulting from biomass combustion processes by Distric Heating Plants (DHP) located in South Tyrol. The current use of the ashes is to produce compost, or in the cement sector or, as a last resort, to be deposited in landfills. While considering the different benefits deriving from the reuse of ashes, however, it is necessary to find new applications for this waste to avoid landfill, as the production of biomass energy will tend to grow over time, according to some recent trends. For example, the production of geopolymers that could be used for cement production is being developed. The latter is currently produced through the use of non-renewable materials. On the contrary, the use of combustion ash, due to their intrinsic properties, would lend itself well to this purpose by implementing a circular process. Based on these considerations and taking as a reference the

[29] The project is financed in the Alpine Space Interreg Programme and it contributed to Eusalp AGs 2, 6 and 7.
[30]https://www.alpine-region.eu/projects/circulalps-innovation-foster-sustainability-and-circular-economy-alpine-forestry-value
[31] The project is co-financed by the European Union (Alpine Region Preparatory Action Funds - ARPAF)

development of EIPs, it could be interesting to create industrial parks in the areas of South Tyrol where DHPs are located and aimed at using waste such as ashes. In addition, the presence of heat and electricity production plants could also make it possible to guarantee the necessary renewable energy supply to the companies of the Industrial Park.

Another interesting project is Circular 4.0[32] which explores how digital systems can support the development of circular actions[33]. The development of new technologies makes it possible to create new innovative business models in the circular economy. Circular 4.0 contributed to the transition to a circular economy in the Alpine area by focusing on SMEs and economic operators. The project aims to evaluate the digital technology readiness of SMEs and proposes an assessment tool aimed at these companies with the aim of accelerating their process towards the circular economy. It could be interesting, for the purposes of the ECOLE project, to analyse such a tool and verify possible application to EIPs.The Cradle-ALP [34]project focuses on replacing chemical, fossil or unsustainable materials with more sustainable and biodegradable one. The project is mainly addressed to policy maker, industries and business support organization to change towards Cradle-to-Cradle approaches, circular design and circular substitution in the Alpine region.

As part of the circularity projects concerning territorial areas and business aggregations, the GreenCycle project results very interesting. This projects' aim is to develop and promote circular economy in medium-sized cities in the Alpine Space. Its implementation focused on developing several axes: circular economy strategies in partner cities, regional skills to support circular economy projects, and tools such as a knowledge base, a toolbox and a digital marketplace. Financed by the Interreg Alpine Space programme, it includes five partner pilot cities. For our purposes, the project is interesting because it also involves the industrial sector in circular development projects on the territories scale of some selected cities. One of the pilots concerns the town of Maribor, in Slovenia. This city has embarked on a policy of circular economy based on 3 axes: waste, water management and energy. The project has seen the creation of the Wcycle Institute Maribor by five Maribor public utility companies operating in the fields of waste management, construction, district heating, water supply and public transport.

[32] CIRCULAR4.0 is co-financed by the European Regional Development Fund through the Interreg Alpine Space programme

[33] The project sustain Eusalp AG 1.

[34] https://www.alpine-space.eu/project/cradle-alp/

Within the framework of this programme, 20 projects related to the circular economy have been selected and will be gradually implemented as a construction waste treatment unit, a biomass power plant for energy production from wood and waste water recovery. One of the first operational projects is the waste sorting centre which started operating in July 2018. The beneficial effects of this policy of developing the circular economy can be seen in the territory of Maribor through the development of new activities allowing the creation of green, local and non-relocatable jobs.

Although this project is not related to the development of industrial parks, there are important similarities with EIPs. The project foresees the possibility of creating synergies between utilities of different sectors in order to optimize energy flows, water flows and waste use in a logic of integration between companies, utilities and communities served in the area.

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