Concept and Practice of the Circular Economy

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Concept and Practice of the Circular Economy.

Turning goods at the end of their service life into resources, closing loops in industrial ecosystems and minimizing waste

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Abstract

Circular Economy (CE) is a concept that would turn goods at the end of their service life into resources for others, closing loops in industrial ecosystems, minimizing waste and following sustainable methods. A report of the European Commission in 2014 estimated that with a Circular Economy type transitions in the EU countries can create 600 billion euros annual economic gains for the EU manufacturing sector. Even China after many years of rapid economic growth adopted the Circular Economy concept in the last two 'Five Year Plans' drawn up by the Chinese government. China understands that is imperative to change course in the use of raw materials, energy sources and industrial processes which produce excessive waste. Circular Economy is connected with sustainable development. It is a system of resources utilization where reduction, reuse and recycling of materials prevails, cutting down waste to a minimum and with the use of biodegratable products recycle the rejected products back to the environment.

In the last decades many national and international companies followed research on Circular Economy and incorporated projects related with best practices of CE. The scientific literature contains large number of best practice examples of CE from well known commercial enterprises and businesses or research groups in industrial countries. The majority of practices are useful models to recycle and reuse materials for the same or new products, reducing energy use and offering drastic reduction of waste. Germany, United Kingdom, France, the USA, the Netherlands, China, Denmark, Sweden, Norway, Finland and other countriers have advanced projects of Circular Economy after the concept was researched extensively and new solutions and innovations on reuse were discovered. The textile sector, the clothing sector and the durable goods sector (electrical, electronic, carpets, furniture, etc) have advanced some interesting examples of circular economy. This review presents the basic concept of CE and its association with sustainable development in developed and developing countries. Also, the review presents pioneering CE solutions that benefits the environment, the climate and the economy. Case studies and examples of companies that design their products in such a way that the lifetime of the products is extended and materials or components can be reused and recycled at a high value in the economy.

Introduction : The concept of Circular Economy

Circular economy (CE) is currently a popular concept for future sustainable development promoted by the European Union and by several national governments (China, Japan, UK, France, Canada, The Netherlands, Sweden, Finland, etc). Also, many business enterprises around the world have introduced CE in their manufacturing sectors to shave energy and raw feeding materials. But for the moment the concept of circular economy is a collection of vague ideas from several technological fields and semi-scientific conceps. [1]

A report of the European Commission in 2014 estimated that with a Circular Economy type transitions in the EU countries can create 600 billion euros annual economic gains for the EU manufacturing sector alone.[2] Various international economic organizations estimated that the global economy would benefit 1,000 billion US dollars annually.[3] China was the first country in the world, that adopted a law for the circular economy in 2008.[4]

The initial concept of materials cycles has been around since the dawn of industrialization and was practiced by industrial businesses beacuse it reduced negative environmental impact, saved in energy consumption and made economic sense. But the linear throughput flow model in industry and other businesses has dominated the overall industrial development causing serious environmental pollution and extensive use of limited natural resources. The Circular Economy approach focused on product, component and material reuse, remanufacturing, refurbishment, repair, cascading and upgrading. Also, reduced the energy needs by advocating alternative sources, such as solar, wind, biomass and waste-derived energy utilization throughout the product value chain.[5,6] Also, the concept of cradle-to-cradle was developed at the same time, which is a biomimetic approach to the design of products and systems that models human industry on nature's processes viewing materials as nutrients circulating in healthy, safe metabolisms.[7]

Ecological economics has a long tradition in recycling and other Circular Economy-type concepts on the macroeconomic level. Also on the microeconomic level, Circular Economy-type scientific papers have been published in ecological

economics. These papers addressed the problem of eco-efficiency or industrial ecology.[8-10]

The Circular Economy concept represents the most recent attempt to conceptualize the integration of economic activity and environmental wellbeing in a sustainable way. For example a set of ideas for the CE has been adopted by China as the basis of their economic development. The Circular Economy places emphasis on the redesign of processes and cycling of materials, which may contribute to more sustainable business models and maximize ecosystem functioning and human well-being.[11]

The initial concept for CE started in 1983, when the United Nations General Asembly asked the then prime minister of Norway Gro Harlem Brundtland to establish and independent commission to explore 'a global agenda for change' with the intention of formulating 'long-term environmental strategies for achieving sustainable development by the year 2000 and beyond'.[12]

The Circular Economy has featured in the last two 'Five Year Plans' drawn up by the Chinese government and is being operationalized in China.[13] The concept of the CE has been proposed in the last decade by many Non Govermental Organizations (NGOs) in developed countries. However, as the Circular Economy is relatively new in its conceptualisation and implementation, there may also be tensions and limitations inherent in its appropriation and application.[14,15]

Circular Economy and sustainable development

In the last decades there was a pressing need worldwide for a transition to an environmentally friendly industrial and economic development and sustainable sociotechnical systems. Today, evidence has accumulatedf from research that the global environmental conditions and the unsustainable use of natural resources has put high pressure on Earth's life-support systems. Biodiversity loss, waste of fresh water resources, soil desertification from excessive land use for food production, increasing air pollution in urban areas, plastic pollution in the oceans, and dramatic climate changes are some of the most serious environmental problems encountered and investigated to great length in the last decades.[16-18]

Taking as an example the cyclical nature pattern, Circular Economy can be a system of resources utilization where reduction, reuse and recycling (3R principles) of elements prevails, cutting down waste to a minimum and with the use of biodegratable products recycle the rejected products back to the environment.

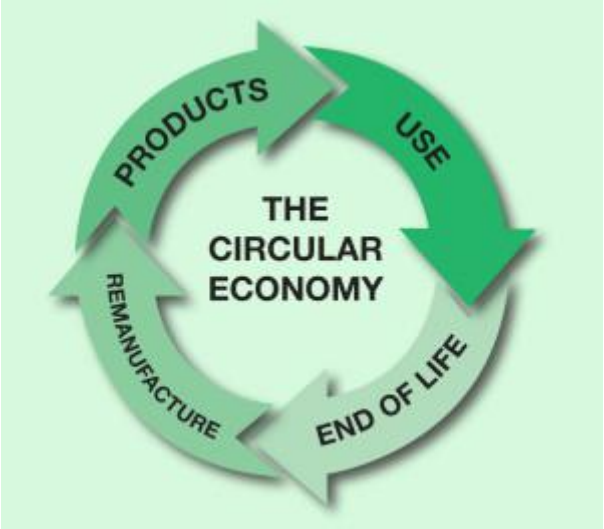

Figure 1. The Circular Economy model promotes the reuse of global natural resources The average European consumes 14 tons of raw materials and generates 500 Kg of waste every year. The USA with 5% of the world's popualtion used 24% of global energy resources and every American generates 2 Kg of waste per day. Many products-materials can be reused or repaired, thus reducing waste. [https://www.therecycler.com/posts/who-is-supporting-the-circular-economy/].

The Circular Economy model promotes the resiliency of natural resources. It aims to replace the traditional linear economy model of fast and cheap production and cheap disposal with the production of long lasting goods that can be repaired, or easily dismantled and recycled. A model of production based on a circular economy may seek to extend the useful life of the product, but also favours the possibility of repair, refurbishment and reuse of products before their actual end-of-life (when it will be recycled into materials that become raw resources). The circular economy model aims to emulate processes similar to those that occur in natural environments.[19]

There is no agreement among axperts on the notion of sustainable development, the ways that circular economy, linear economy and sustainable development are linked and compared can differ significantly. Some scientists in environmental sciences perceive "sustainable development" as a set of initiatives that have been implemented within a linear thinking, thus for them sustainable

development and linear economy have become inseparable. The circular economy therefore offers a solution where sustainable development, when implemented in a linear economy model of production, is perceived as a failure. For scientists in environmental economics sustainable development is a concept that remains independent from past unsuccessful initiatives. Sustainable development is a society objective defined at the macro-level and includes broad notions of ecological, economic and developmental sustainability, while the circular economy approach is mainly defined at the micro-level through a model of consumption and production. If the application of circular initiatives brings better results towards sustainability, then the circular economy becomes a tool for sustainable development.[20,21]

The Circular Economy in the European Union

In the past decade many times the European Parliament debated calls from the European Commission to put forward an ambitious proposal to facilitate a transition towards a circular economy.[22,23]

In 2015, a report on Circular Economy was presented in the European Parliament. The member of the European Parliament and expert on circular economy Sirpa Pietikäinen (she was and economist and former Finnish Minister of Environment, 1991-1995). Her report: “Resource efficiency: moving towards a circular economy” was adopted by the Environment, Public Health and Food Safety Committee of the European Parliament.[24]

In her report she argued that….” Saving natural resources is not only saving raw materials for future generations, but creating multiple benefits starting from reducing waste and ending with new innovative business opportunities. The committee endorsed the approach of the European Commission's Communication on designing and innovating a circular economy. Experts considered that it is a vital step for the EU to use resources more efficiently and to reduce resource dependency and also to make savings in material costs. A smart eco-design of the products means the birth of the lease economy where products become services and also the repairing, reusing and recycling of the products, where products do not become waste after they are no longer in use. This is a major paradigm change where Europe needs to produce the same welfare for the people, better competitiveness for

European industries and profits for companies. To measure this change Europe needs commonly-agreed and harmonised indicators and targets. Business-driven studies demonstrate significant material cost-saving opportunities for EU industry and a potential to boost Gross Domestic Product (GDP) in the EU countrioes by up to 3.9% by creating new markets and new products and creating value for business. The Commission has calculated that increasing resource productivity by 2% would create 2 million new jobs in the EU by 2030. As Europe is more dependent on imported resources than any other region in the world, moving towards a circular economy also strengthens Europe's security. It is an economical and ecological win-win scenario".[24]

Figure 2. After **a**doption of EU Circular Economy (CE) Package in December 2015, more than half of the initiatives included in the Action Plan have been delivered. In 2018 the first achievements of the European CE Stakeholder Platform, the Commission and the European Economic and Social Committee hosted a CE Stakeholder Conference on 20-21 February in Brussels. [https://circulareconomy.europa.eu/platform/en/circular-economy-stakeholder-conference-2021-february-delivering-circular-economy-whats-next].

The scientific community has recognised that the global situation is approaching to critical limitations in respect to natural sources, production of waste, and air and water emissions and levels of pollution. The circular economy prospect is a convincing, strategy, which aims at reducing both input of virgin materials and output of wastes by closing economic and ecological loops of resource flows.

A recent paper (2015) assessed the circularity of global material flows. According the estimates, all societal material flows globally and in the European Union (EU-27) are traced from extraction to disposal and presented for main material groups for 2005. The analysis showed that while globally (roughly) 4 gigatonnes per year (Gt/yr) of waste materials are recycled, this flow is of moderate

size compared to 62 Gt/yr of processed materials and outputs of 41 Gt/yr. The research group has two expalantions for the low degree of circularity: First, 44% of processed materials (globally) are used to provide energy and are thus not available for recycling. Results are presented at the level of main material groups: biomass, fossil fuels, metals, waste rock, and industrial and construction minerals. Second, socioeconomic stocks are still growing at a high rate with net additions to stocks of 17 Gt/yr. Human-made material stocks accumulating in buildings, infrastructure, and machinery, play a crucial but underappreciated role in shaping the use of material and energy resources. Also, education, jobs, social standing, urban prosperity, airtransport, tourism play important roles. Despite having considerably higher end-of-life recycling rates in the European Union (27), the overall degree of circularity is low for similar reasons. The researchers suggested that the strategies must target the output side (end of pipe). The big change will be to shift to renewable energy production. Also, there is a global need for a significant reduction of societal stock growth, and decisive eco-design are required to advance towards reuse of materials and support for a Circular Economy in all fileds.[25-27]

The European Circular Economy Stakeholders Platform, #stakeholderEU, Good Practices includes (2018) more than 150 relevant practices, innovative processes and 'learning from experience' examples on the Circular Economy concept in Europe.[28]

Examples of the Circular Economy concept in practice

The literature is full of best practice examples of Circular Economy from various businesses or research groups in industrial countries. The majority of practices are useful models to recycle and reuse materials for the same or new products, reducing energy use and offering drastic reduction of waste.

Germany, UK, France, the Netherlands, China, Denmark, Sweden, Norway, Finland are countries that have advanced projects of Circular Economy after the concept was discussed in scientific circles. The textile sector, the clothing sector and the durable goods sector (electrical, electronic, carpets, furniture, etc) have advanced some interesting examples of circular economy.[29]

The textile and clothing industry

The clothing industry is among the tope ten largest polluters in the world. The clothing-fashion industry is a complicated business involving long and varied supply chains of production, raw material, textile manufacture, clothing construction, shipping, retail, use and ultimately disposal of the waste garment. The textile and clothing industry is interesting in relation to Circular Economy initiatives for several reasons. The Danish Ministry of Environment has decided clothing and textiles is one of five focus areas of the Danish Resource Strategy of November 2013. Also, in 2008 the French government established a legal framework for textile recycling that included Extended Producer Responsibility (EPR) and the establishment of taxation correspondingly.[30,31]

Swedish men's wear company Nudie Jeans: The company operates in the maintenance, reuse, refurbishment and recycling loops. Although Nudie Jeans manufactures different garments, jeans made out of 100% organic cotton constitute the core business. Nudie Jeans has established a return system, where customers receive a 20% discount off a new pair of jeans on return of an old pair in stores in London, Gothenburg and Stockholm. The returned jeans are washed, mended and subsequently put up for sale in the stores as second-hand jeans (Nudie Jeans 2014, Online shop, Post recycle rug denim. Available: http://www.nudiejeans.com/shop/denim-denim/p/2642). If the jeans are worn out, and thus not possible to reuse, they are recycled instead under three such recycling initiatives on its website. In addition to the return system, the company offers free repairs of jeans in selected stores and sends repair kits free of charge to customers.

The RESYNTEX project. The European Union (28 countries) textile industry generates waste estimated at 16 million tons per year. Much of this waste is thrown in landfills or incinerated, with a high environmental impact and at great cost. Valuable resources held within the waste are also lost. The RESYNTEX project received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement 641942. The RESYNTEX has 20 project partners from across 10 different EU member states. In July 2018, 64 companies signed the 2020 Circular Fashion System Commitment. RESYNTEX aims to create a new Circular

Economy concept for the textile and chemical industries. Using industrial symbiosis, it aims to produce secondary raw materials from unwearable textile waste. Other aims are: Design a complete value chain from textile waste collection through to the generation of new feedstock for chemicals and textiles; Improve collection approaches while increasing public awareness of textile waste and social involvement; Enable traceability of waste using data aggregation. The collected data will evaluate the performance of the new value chains by means of a life cycle assessment (LCA) and life cycle costing (LCC); develop innovative business models for the chemical and textile industries; demonstrate a complete reprocessing line for basic textile components, including liquid and solid waste treatment [http://www.resyntex.eu/the-project].[32]

Figure 3. The RESYNTEX project aims at designing, developing and demonstrating new high environmental impact industrial symbiosis between the unwearable blends and pure components of textile waste and the chemical and textile industries.

Circular Economy for the durable goods sector

Durable goods include product groups such as automobiles, machinery, furniture, carpets, radio, TV, communication equipments, office machinery, computers, medical equipment, etc. These product groups often contain significant quantities of rare earths, metals including precious metals, plastics and other non-renewable resources. At the same time, large amounts of energy are required to process these raw materials into refined durable goods. The potential for

environmental and economic savings from optimizing the resource efficiency of individual products and of durable goods industries as a whole is substantial, and prospective materials savings for these product groups have been estimated at somewhere between US$ 340 and 630 billion only at EU level.[29]

Figure 4. **Carpet Recyclling.** It takes place in the last decade in many European countries. Celebrating 10 years of Resource Recovery' is the theme for Carpet Recycling UK's 2018 Annual Conference and Awards Event, Birmingham, UK. There national and international industry-backed associations for recycling and reusing waste carpets.

Case Study: Remanufacturing of carpets, **Dutch carpet manufacturer Desso.**

The Desso is a Cradle-to-Cradle carpet company striving for a new circular economy material stream. Desso was among the first companies to strive for closed loop manufacturing in the carpet industry. Desso's innovation strategy is concentrated in 3 key areas: Creativity, Functionality and Cradle to Cradle. For Desso, creativity is synonymous with CARPETECTURE®, which is a powerful example of Desso's commitment to creative carpet design and its dedication to meet the needs of architects, interior designers, building owners and end users. In the field of functionality, Desso develops pioneering solutions that make a difference for health and wellbeing. Desso's efforts began around 2007, and since then it has developed a number of Cradle-to-Cradle certified carpet tiles. The certification was a first step for Desso since only non-harmful, reusable raw materials were used for the production

of the new line of carpet tiles. This strategy allowed for the development of a remanufacturing process for the tiles. Recycling of carpet tiles (Take Back Programme from 2008). Desso received €1.6 million grant (50% of the total budget) from the European Commission's Competitiveness and Innovation Programme to roll out the Take Back Programme in Benelux, France, Germany and the United Kingdom.[33]

CE Case Study: Panasonic and PETEC. In Japan, the well known electronics company Panasonic started operating in 2001 a recycling facility, Panasonic Eco Technology Centre (PETEC for short). [http://panasonic.net/eco/petec/]. PETEC was opened to meet the requirements of the Japanese Law on recycling of durable goods. This is similar to the Waste Electrical and Electronic Equipment Directive (WEEE Directive) of the European Community Directive 2012/19/EU on Waste Electrical and Electronic Equipment (WEEE) which, together with the RoHS Directive 2002/95/EC, became European Law in February 2003. The facility PETEC was established to achieve high quality recycling and operates more as a reverse factory than a traditional recycling facility. Since starting operations PETEC has recycled over 11 million products, producing enough steel to make 228,000 new cars, and enough aluminium to make 140 new aeroplanes. Plastics have been particularly challenging as European legislation provides no exemption from chemical regulations for recycled materials. For this reason, shredder residues have historically been discarded or used as fuel. PETEC has been able to develop technology capable of sorting three major types of resins: polypropylene (PP), polystyrene (PS), and acrylonitrile butadiene styrene (ABS) with an accuracy of at least 99%. This is achieved using Panasonic's original near-infrared (near-IR) identification technology which sorts and recovers single resins but also detects specific hazardous substances and removes them during sorting. The successful establishment of PETEC depended on the enlightened approach to waste electrical equipment legislation in Japan, aided by strong industry-government cooperation. [34]

CE Case Study: Hewlett-Packard (HP) Closed Loop Cartridge Recycling. From 2010 the HP which is a major print cartridge manufacturer, has implemented a closed loop approach to cartridge manufacture and is making cartridges from

recycled polyethylene terephthjalate, PET (RPET) and recycled polypropylene (RPP). Polypropylene is used in a significant percentage of HP's inkjet supplies. This new initiative became fully commercialised in early 2014. The RPP programme combined with the existing RPET initiative has led to more than 75% of original HP cartridges containing recycled plastic. In addition, 24% of HP LaserJet toner cartridges contain recycled plastic. Through this process, HP has kept 566 million cartridges, 498 tonnes of polypropylene hangers and 2.5 billion post-consumer bottles out of landfill. More than 80% of our ink cartridges and 100% of HP LaserJet toner cartridges are now manufactured with "closed loop" recycled plastic.[35]

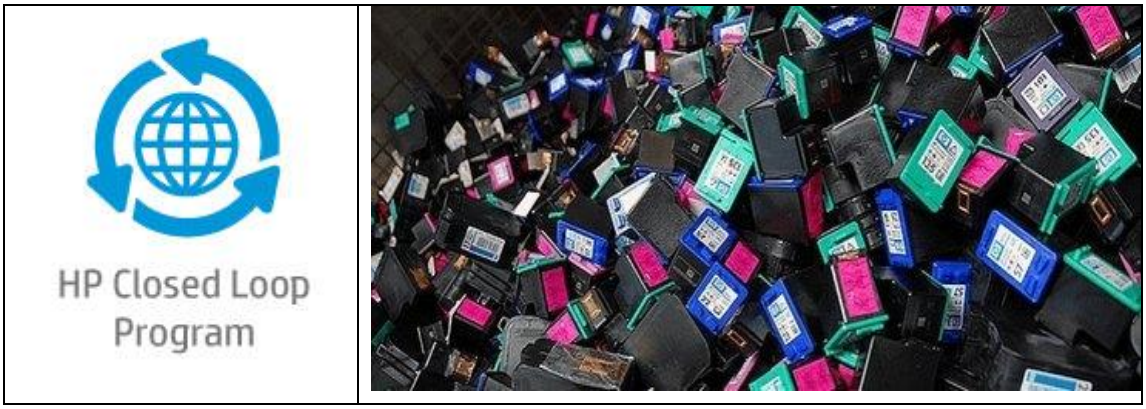

Figure 5. All HP ink and toner cartridges that return to HP Planet Partners go through a multiphase, "closed loop" recycling process where materials are separated and refined for use as raw material in new original HP ink and toner cartridges and everyday products.

CE Case study: Samsung and Dell Repair Centres. Both companies have the strategy to bring customer support interaction closer to their customers by providing strategically placed face to face offices for repairs. Samsung's work includes providing two and 10 year warranties on "key product components", as well as offering "premium repair centres" with one-hour repairs and smartphone and TV apps for remote repair. Also, Samsung uses 30% recycled plastic in desktop monitors from 2015 onwards, while its smartphones include recycled plastic in earphone cases, inner trays and chargers. Dell company has a technology recycling programme across 83 nations, has recovered 1.6 billion pounds of electronics since 2007, and already sees "many of its products use recycled plastics", with these also "designed to be fully dismantled so that its parts can be recycled or reused". Dell uses the

Closed-loop systems, with recycling and re-using materials repeatedly. This reduces the need for virgin materials while avoiding the creation of waste. A key component of closed-loop systems is the idea that recycling comes from the same product or same industry. In the case of Dell, this means recycling computers back into new computers. Samsung has open Support Centres across most developed countries within easy reach of customers. These repair centres offer full-on site repair facilities for all Samsung smartphones and tablets and are open for business customers. All repairs are carried out by fully trained engineers, technicians and support staff using genuine Samsung parts, which are both in and out of warranty, hardware and software faults.[36]

Circular Economy in China, successes and challenges

China witnessed a remarkable period of rapid growth shifting from a centrally planned to a market based economy. China was the world's fastest-growing major economy, with growth rates averaging 10% over 30 years (6.8% for 2017). China is now the second economic and industrial superpower after the USA. The price of the rapid development was characterised by high levels of air and water pollution and depletion of natural resources. China has more than 1,500 industrial parks (with output value for more than 60% of China's gross industrial output). However, these parks are dominated by heavy polluting industries which are a source of degradation of the environment (air and water pollution) and massive production of solid waste. In the face of limited resources and high energy consumption, China implemented a new national strategy for Circular Economy (CE) in 2005, which aimed to obtain high resources and energy efficiency by means of "reduce, reuse and recycle".[37,38]

In 2012 China proclaimed the *"Twelfth Five-year" Plan for National Economy and Society Development*" that was approved by the State Council to promote green development and the CE in China. The plan provided for the economizing and effective utilization of resources, including utilization of waste resources. The plan put forward the development goal of Circular Economy for the first time, meaning that resource productivity would increase by 15% over the five-year period. It also

put forward the requirements of promoting circular production modes. Successful enforcement of a CE can be seen as a way for China to tackle its urgent problem of environmental degradation and source scarcity. A critical example of CE in the city of Dalian of China (Dalian is a major city and seaport in the south of Liaoning Province), provided a panorama of how this CE strategy has been developed and implemented in China (compared with the cities Beijing, Shanghai and Tianjin). The review identified the underlying problems and challenges for this national CE strategy. The research group concluded that it is obvious that local governments have had some success in turning their local economies into circular ones, but there are challenges that impede the successful implementation of the CE in China: lack of reliable information, shortage of advanced technology, poor enforceability of legislation, weak economic incentives, poor leadership and management, and lack of public awareness.[39]

In the last decade China's consumption of the world's resources approached crisis levels. China produces 46% of global aluminium, 50% of steel and 60% of the world's cement. In order to produce all these materials China's industry consumes more raw materials (25 billion tones) than the 34 top industrial countries of the Organisation for Economic Co-operation and Development (OECD).[40] China's industrial production has been proved to be inneficient and wasteful (in terms of raw materials and energy). China generated 3.2 billion industrial solid waste in 2014, of which managed to recover only 2 billion tons (recycling, composting, incineration or reuse). In comparison the European Union (28 countries) generated 2.5 billion tons of industrial waste, of which managed to recycle or used for energy 1 billion tons. China is expected by 2025 to produce 25% of the world's municipal and industrial waste.[41]

Additionally, in the last decade China was the world's largest importer of municipal and industrial waste from idustrial countries (used for energy and for paper production). But in 2018 China decided to stop the process and banned 24 types of scraps from entering its borders (especially from EU, Japan and USA). The ban was hailed as a big win for global green efforts by environmentalists, but also force other countries to better manage their own trash.[42]

China started promoting the recirculation of waste materials through setting targets and adopting policies, financial measures and legislation. The ultimate goal is a Circular Economy (CE). The country's planning agency, the National Development and Reform Commission (NDRC) and bodies such as the Ministry of Environmental Protection have since developed circular-economy principles and promoted exemplars of industrial symbiosis.[43]

Figure 6. Suzhou city (left) about 100 km northwest of Shanghai with a total resident population of 10.5 million. Suzhou Science and Technology Industrial Park (right) is a key project of Jiangsu Coastal Development and the Combined Development across the Yangtze River. Suzhou's economy is based primarily on its large manufacturing sector—China's second largest—including iron and steel, IT and electronic equipment, and textile.

The Suzhou New District (SND, one of the specially designated regions for technological and industrial development in China covers an area of 52 km^2 and is located 5 km west of Suzhou, in the Jiangsu province) is an exemplar of circular-economy initiatives in China. In 2005, it was selected as one of the first 13 industrial parks to participate in China's national circular-economy pilot programme. In 2008, it was one of three national eco-industrial park demonstration sites in the country, along with the nearby China–Singapore Suzhou Industrial Park and the Tianjin Economic-Technological Development Area. By 2014, the SND hosted more than 16,000 enterprises and almost 4,000 manufacturing businesses. Gold and Coppper recirculation of metal resources from printed-circuit-board supply chain was indentified as a useful CE project. A venture was formed with Dowa Metal in Japan to establish an advanced metal-recycling business in the SND. Electronic-waste

companies such as Dowa reclaim the copper and water from the sludge created by circuit-board processing. In other examples, a producer of kaolin (a type of clay) turns residues from mining into inputs for the production of sulfuric acid and construction materials; a paper manufacturer takes waste ammonia from a chemical company to use for desulfurization in its process; and industrial water recycling is undertaken on site. The economic benefits are clear. Recycled, regenerated and locally sourced raw materials are usually cheaper, increasing profits. Primary industries such as iron, steel and aluminium need strong targets for recirculation.[43-45]

Examples of businesses and products with Circular Economy practices

Denmark and Circular Economy

In last decade more and more Danish companies are becoming aware of the significant growth opportunities in the circular economy. Danish companies are developing pioneering circular economy solutions that benefits the environment, climate and economy. Other companies are designing their products in such a way that the lifetime of the products is extended and materials or components can be reused and recycled at a high value in the economy. In 2015, Denmark was awarded the World Economic Forum's Young Global Leaders award 'The Circulars' for being a global front-runner in exploiting the potential for a circular economy.[46]

Carlsberg Group. Developing the world's first biodegradable beer bottle. One of the challenges the Carlsberg Group focuses on is packaging, as around 45% of their CO2 emissions come from the company's packaging. They want to reduce this number by encouraging consumers to recycle more, minimise material usage and by developing new environmentally friendly packaging types. The Carlsberg Group have initiated a partnership with Danish company ecoXpac, Innovation Fund Denmark and the Technical University of Denmark to develop the world's first fully biodegradable beer bottle made from wood fibre –**the Green Fiber Bottle**. The bottle will be as light as a PET bottle, while having the advantage of being created from bio-based sources. The project is one of the activities in the Carlsberg Circular Community, which is the Carlsberg Group's partnership platform to develop more sustainable products with partners from across the world. The community aims to eliminate the concept of

waste by creating sustainable products and a more circular economy in an increasingly resource-scarce world.[47]

United States of America and Circular Economy

The United States has not been a trend setter in the circular economy field although from 2003 the United States Environmental Protection Agency recognized the need for a fundamental change to its core legislation, if effective waste and materials management was going to be achieved. To develop new circular economy opportunities and realise their ambitions faster in the USA the Ellen MacArthur Foundation has launched a US chapter of its Circular Economy 100 (CE100) program in 2016, including corporations, universities, city and government authorities, commercial brands such as Google, Cisco, Coca-Cola, eBay, Apple, Novelis, IBM and others. The US CE100 program was the result of a new study by the US Chamber of Commerce Foundationthat estimating that 5,589 largest publicly traded companies in the USA produce 342 million metric tons (mt) of waste that were directed to landfills and incinerators in 2014. [Ellen MaArthur Foundation. Launches US Circular Economy Program, 26.5.2017, https://www.environmentalleader.com/2016/03/ellen-macarthur-foundation-launches-us-circular-economy-program/].

Levi Strauss clothing business. With around 10 billion kg of clothing, shoes and textiles finding their way into U.S. landfills each year — including untold tons of jeans — Levi's is working on some interesting short- and long-term circular economy initiatives aimed at taking a chunk out of this statistic. Every Levi's store accepts old clothes and shoes of any brand, which the company collects and repurposes or recycles with its partner, I:CO. The collected clothes are transformed into things such as insulation for buildings, cushioning material and new fibers for clothing. Meanwhile, Levi's is working to establish an infrastructure that supports closed loop products by 2020. Eventually, the company hopes to be able to recycle old Levi's jeans into new ones.[48]

The Plant ecosystem of 16 food enterprises (Chicago). Many US cities have economies that are as big as entire countries, possessing characteristics (size, density, talent) that make them well-positioned to both drive the transition to the

Circular Economy. The cities are becoming more urbanised and feeding citizens encounter many challenges to be more effective and less wasteful. The Plant, an ecosystem of 16 food enterprises located in an old meat-packing building in Chicago, could be a model for future urban food production that fulfils this. The Plant's ambition is captured in their mission statement: "To develop circular economies of food production, energy conservation and material reuse, while empowering people of all backgrounds to make their cities healthier and more efficient".[49]

DSM-Niaga, US example for recyclable carpets. In the U.S., more than 2 billion kg of carpet is landfilled every year, making it one of the most common products in landfills today. DSM-Niaga is a joint venture that is producing the world's first and only fully recyclable carpet. The Niaga® Technology for carpet production is based on using a simple set of clean processes, ingredients, and materials that make the product 100% recyclable. This includes not using latex as an adhesive in the manufacturing process. After the carpet is used, it is sold back to the manufacturer and turned into new carpet. The name "Niaga" means "Again" spelled backward as in true circular fashion, it can be used again and again and again. [Niaga® found ways to meet all performance demands of a carpet by using only one material. This allows for easy recycling after use, back into carpet. https://www.dsm-niaga.com/].

Finland and Circular Economy

Finland has many examples of businesses with CE actvities. The list of enterprises maintained by Sitra has now expanded to cover 54 companies. These forerunners of the circular economy will be among those highlighted when the most influential figures from the world economy gathered in Helsinki for the first ever World Circular Economy Forum (June 2017). In the International Conference were presented the best circular economy worldwide examples, combining business activity with environmental responsibility, and based on the implementation of the UN's Sustainable Development Goals. The conference attracted 1,500 influential figures from the circular economy world, from more than 90 countries. Over 130 top speakers from five continents were present. Speakers included Anirban Ghosh, Chief Sustainability Officer at the Mahindra Group in India; Amra Balic, Managing Director

of the US financial planning and investment management company BlackRock; Janez Potočnik, co-chair of the UNEP International Resource Panel; Ashok Khosla, founder and director-general of the Development Alternatives company; and Achim Steiner**,** who will start as the Administrator of the United Nations Development Programme in June. [50,51]

Netherland and Circular Economy

The Netherlands government has selected 5 economic sectors and value chains that will be the first to switch to a circular economy. These 5 priorities are important to the Dutch economy and have a big impact on the environment. Much is already being done in these sectors to move towards a circular economy, both in the Netherlands and in Europe. The economic sectors are: biomass and food; plastics; manufacturing industry; construction sector and consumer goods.[52,53]

Example of circular economy, Vitens (The Netherlands). Vitens is the largest drinking water company in The Netherlands producing 350 million cubic metres of drinking water and 60,000 tonnes of by-products, such as calcium, iron and humic acid. The semi-public company paid approximately 1.8 million euros per year to eliminate this as waste. These by-products, however, are valuable inputs for other sectors. By changing the production in Vitens factories the process waste has become a product. Now Vitens produces and sells humic acid as a soil enhancer for agri-business.[The Netherlands Circulair, 2018 file:///C:/Users/User/Documents/CE_50+best+practices.pdf].

The Netherlads Circulair is a website with typical and innovative examples of circular economy businesses offering solution to waste, environmental pollution and sustainable development.[54]

Germany and Circular Economy

Although Germany is considered a highly advanced industrial country with exceptional programme for environmental protection, sustaibility projects and advanced waste management. But there is an unsatisfying recovery of secondary raw materials. The Netherlands and the United Kingdom are much more advanced

than Germnay in terms of using secondary raw materials obtained from waste recycling in industry. The explanation is that Germany acquires enormous quantities of energy from incineration, but, in doing so, it burns material that could be recovered and reused. 15% of the materials that Germany uses in industry come from recycling processes, while the other 85% is raw material (petroleum, natural gas, mining products, polymeric monomers). Another problem with Germnay is that waste produced in construction-industry (demolition) is over 90% recycled. These materials are not reused as construction material but rather to construct soundproof motorway barriers. Only 3% of cement is recovered. This means that 97% raw materials are used for every new building. For Germany to change its course will depend on Europe and the Circular Economy package currently being discussed (2017). Germany does not have set specific objectives in terms of material recovery and reducing waste production. The question for Germany remains as to whether the circular economy is an economic or environmental project or both.[55]

Germany has a dedicated Website for the Circular Economy and the best practices. Global Compact. Network Germany. Best Practice-Circular Economy [https://www.globalcompact.de/en/themen/Good-Practices/Umweltschutz/Best-Practice-Kreislaufwirtschaft-bei-Daimler-Kopie.php].

Circular Economy fror the automotive industry in Germany. The automotive industry provides a good example of successful Circular Economy practice. The materials used are usually properly disposed of, providing a high degree of recycling potential. Currently, **Daimler** vehicles consist of around 48% metal and 20% various polymer materials. The manufacturer submits its vehicles to an environmental balancing process, which depicts the material flows and CO_2 footprints. Under the guideline 'Design for Environment' (DfE), vehicles are designed during the early development stage in such a way that they are as resource-friendly and eco-friendly as possible. The specifications of Daimler vehicles stipulate that the proportion of so-called secondary raw materials, including the use of recyclates, will be continuously expanded. Planners therefore envisage an annual check by 2020. The interim target was to use 25% more renewable raw materials and recyclates by 2015 than in the

base year of 2010. This target was exceeded, with 39% higher usage of recyclates and 28% higher usage of renewable raw materials.

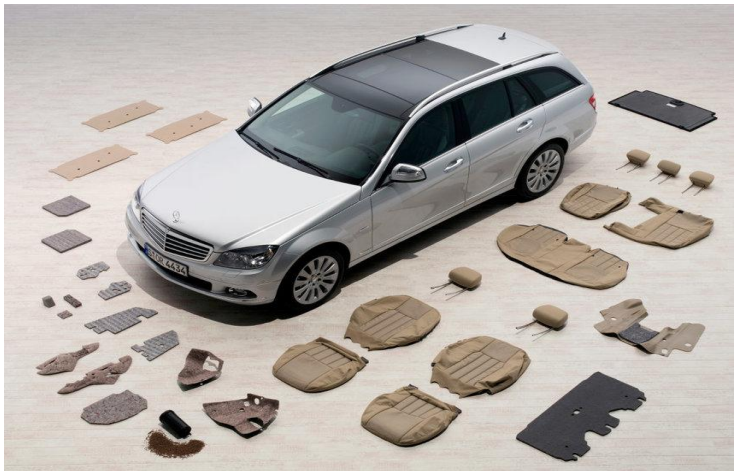

Figure 7. The specifications of Daimler vehicles stipulate that the proportion of so-called secondary raw materials, including the use of recyclates, will be continuously expanded. Planners therefore envisage an annual check by 2020.

In the last decade Daimler vehicles are more environmentally friendly (emissions and the resources they consume over their entire lifecycle). Daimler engineers pay close attention to creating a recycling-friendly design. Up to 85 % of the material in all Mercedes-Benz models is recyclable and as much as 95 % of the material is reusable. Also, Daimler use old cars and separates proven elements of recycling concept which are for resale (inspected and certified used parts by MeRSy Recycling Management workshop disposal system).[56]

France and Circular Economy

The Circular Economy Institute (France) was founded in February 2013, bringing together likeminded stakeholders in France to promote and accelerate the transition towards the Circular Economy. The institute functions as a national multi-stakeholder think-tank allowing the pooling of expertise and good practices of different parties. It also involves many projects that are under development and are expected to emerge in 2015. The Institute already has over 150 member organizations. In 2014 the First Assembly of Circular Economy was launched in cooperation with the French National Environmental Agency (1.000 participants involved in Circular Economy). [Institut De L'Ėconomie Circulaire, source: http://govsgocircular.com/cases/the-circular-economy-institute/].

The Institut de l'Ėconomie Circulaire (IEC) has presented 10 initiatives implemented in four French regions (Auvergne-Rhône-Alpes, Bretagne, Normandie and Nouvelle-Aquitaine) as part of a national programme to generate synergies between businesses (Programme National de Synergies Inter-Entreprises - PNSI).

This ambitious scheme was implemented with support from the French environment and energy management agency (ADEME) and the Environment ministry. The PNSI, launched in July 2015, has led to the formation of a network of more than 500 companies that have participated in a range of workshops to identify opportunities for synergies between businesses in the various territories. Operational support has also been provided to businesses, to help them seize the most promising opportunities.[57]

United Kingdom and Circular Economy)

Zero Waste Plan of Scotland. By publishing the Zero Waste Plan in June 2010, the Scottish government committed itself to shifting towards a more resource efficient economy by reducing resource use, improving efficiency rates and preventing waste. [http://www.gov.scot/Topics/Environment/waste-and-pollution/Waste-1/wastestrategy].

Extending producer responsibility with precycling premiums. Every product has a risk of ending up as waste in ecosystems and causing numerous societal issues. In order to tackle these problems and implement the Circular Economy, the UK-based Blindspot Think Tank proposes to extend producer responsibility to cover the risk of products becoming waste. [http://govsgocircular.com/cases/extending-producer-responsibility-with-precycling-premiums/]

Innovate UK. Helps companies that see a future in a Circular Economy to innovate more quickly and support technologies and business models that back them. 60 business-led projects to date. http://govsgocircular.com/cases/innovate-uk/]

National Industrial Symbiosis Programme. The National Industrial Symbiosis Programme (NISP) is the first national industrial symbiosis programme. It facilitates business opportunities by the trading of assets, resources, logistics and expertise between industries. £1 billion cost savings achieved and £1.4 billion generated in

additional sales. Over 10.000 jobs created 45 million tons materials recovered and reused, 39 million tons industrial carbon emissions reduced and 71 million tons industrial water savings made[source: http://govsgocircular.com/cases/national-industrial-symbiosis-programme/].

According to Recycling International (website, The Netherlands) The top 5 countries with the better CE index are Germany, France, United Kingdom, Czech Republic and Italy. The worst performing countries are Greece, Malta and Cyprus. [58]

Circular Economy in Greece

The Hellenic Federation of Enterprise in Greece (Σύνδεσμος Επιχειρήσεων και Βιομηχανιών) commissioned an assessment of the στate of Circular Economy in Greece in 2016. [59] The report noticed that the Greek legislative and regulatory framework on the CE, as well as the legislative and regulatory barriers identified through cross sectorial assessment is characterised by delays in implementation and failures in actual implementation of the European legal framework on the CE. Also, there are contradictory legislations. There is non transparent and deficient licensing regimes for Circular Economy activities. Greece lacks law enforcement and absence of sufficient audit mechanisms and subsequent delays in the imposition of administrative fines. The consequences of this context relate, among others, to a perceived tolerance of illegality and cultivation of an unfair competition status. The study reveals that most of the sectors are in an early transitional phase towards the Circular Economy. The study mentioned the case of the use of municipal solid waste for RDF (Refuse-Derived Fuel, RDF) in direct combustion or co-combustion systems, namely in the cement manufacturing (Volos), paper and pulp mills or in thermoelectric power plants.[59]

A case example of CE in Greece is the “Appliances Recycling S.A.” A nationwide collective take-back and recycling scheme for all Waste of electrical and electronic equipmement (WEEE) categorie. Appliances Recycling SA a non profit organization has been approved in June 2004 by the Minister of Environment Planning and Public Works for the operation of the Collective System for the WEEE Waste appliaces opportunities in Greece.[60]

Conclusions

Circular Economy (CE) origins are mainly rooted in ecological and environmental economics and industrial ecology theories of the past decades. The idea of economy as a circular system is seen as a prerequisite for the maintenance of the sustainability of human life on Earth. The CE applications encounter intractable material and energy problems, disadvantages to current models of production and big technological challenges. Despite the problems CE is receiving increasing attention worldwide as a way to overcome the current production and consumption model based on continuous growth and increasing resource throughput. By promoting the adoption of closing-the-loop production patterns within an economic system CE aims to increase the efficiency of resource use, with special focus on urban and industrial waste, to achieve a better balance and harmony between economy, environment and society.

The Ellen Macarthur Foundation (2013) promoted the concept of CE supported by attributes to more recent theories such as regenerative design, performance economy, cradle to cradle, biomimicry and blue economy as important contributions for the further refinement and development of the concept of circular economy.

The 3R principles (Reduction, Reuse, Recycle) of CE can be integrated by three additional principles developed within the Ellen MacArthur Foundation Report (2012). The first one, *Appropriate Design*, stresses on the importance of design stage in finding solutions to avoid waste discharge in landfills. The second, introduces a reclassification of the materials into "technical" and "nutrients". The technical materials (metals and plastics) are designed to be reused at the end of the life cycle while the nutrients or biological nutrients, that in general are non-toxic, *"*can return safely to the biosphere or in a cascade of consecutive uses*"*. The third additional principle, "renewability", places renewable energy as the main energy source for the Circular Economy, to reduce fossil energy dependence and enhance the adaptability (resilience) of the economic system towards oil negative effects.[61]

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