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CIRCULAR ECONOMY QUALITY CRITERIA IN THE KOKKOLA INDUSTRIAL PARK
Case study: Boliden Kokkola

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ABSTRACT

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The conscious and unconscious destruction of the planet Earth has proven the need for better processes and habits to counter the status quo. Dealing with global warming requires more than just tackling the consequences but addressing the problem from the get-go. This demands engineering processes that diminish the cradle to the grave mentality. The geometric increase in human population and the diminishing resources demand a better way of doing things not just for the present generation but also generations to come.

This thesis work elaborates on the concepts that have gradually shaped the circular economy with working examples around Europe. This report reviews the Circular economy (CE) indicators at the macro and micro levels not forgetting the CE indicators classification framework. Th main target was presenting the circularity around the Kokkola industrial park specifically in Boliden.

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1 INTRODUCTION

The increasing cost of tackling global warming is reshaping the cradle to the grave mentality of the world to a cradle to cradle approach in tackling this problem. The geometric increase in the global population demands an increase in the need for resources coupled with the depletion of resources, propels the rethink of resource consumption and disposal. Industries had little or no motivation to completely commit to sustainability as it concentrated solely on meeting present needs without endangering the future. Circular economy encompasses sustainability and economic feasibilities to approaching the damning effects of global warming and environmental adversities of our industries.

The socioeconomic and environmental effects of urbanization and industrialization is experienced across the globe hence, critical and target specific solutions are required to curb these adversities. The principles of waste and pollution elimination, recycling and reuse of materials, and reconstructing natural systems which form the basis of circular economy is crucial for minimizing our environmental impacts. The essence is transforming the way goods and services are produced and used. Targeting industrial parks which are collectives of industrial businesses in a specific area to optimize collaborative opportunities with global economy can be a vital weapon in the fight against global warming.

The concept of circular economy has been taken up by many countries, legislatures drawn up and policies adopted to make its implementation feasible. We could say in a few years to come circular economy will be the new normal in the global scale. Considering the case of Finland, a value creation potential of 1,5 – 2,5 billion Euros which is a reserved appraisal by 2030. Circular economy goes beyond raw material pathway and waste. It also involves maintenance, reuse and remanufacture of equipment.

The aim of this thesis is to elaborate the circular economy practices and strategies of the Kokkola Industrial park (KIP), specifically Boliden. Secondly, the circular economy indicators employed in the KIP and how they are measured. Finally, propose new circular economy indicators for the KIP.

Section 2 of this work dives into the circular economy concept in general and circularity in industrial parks with some examples. Section 3 will focus on measuring circularity by looking at indicators of circular economy and how they are measured. This section will also target the main economic, social and environmental impacts of circular economy transition. In section 4 the specific case of circular economy in the Kokkola Industrial Park will be handled concentrating on existing industrial synergies, circularity, specifically in Boliden. The last part of the thesis presents some conclusions based on the available literature and contact with some other Industrial Parks. This section will also try to bring out possible suggestions on new indicators that can be helpful to the KIP.

2 CIRCULAR ECONOMY

Sustainability is the pivot of circular economy which implies monitoring, minimizing, and eliminating waste flows through circulation not strictly consumption of materials (Arponen, Granskog, Pantsar, Stuchtey, Törmänen, Vanthournout, 2015). Circular economy has roots in many of the sustainable development goals (SDG) approved by the United Nations. Some of these goals are no poverty (SDG1), responsible consumption and production (SDG12), sustainable cities and communities (SDG11), and the advancing comprehensive and sustainable industrialization and innovation (SDG9). As of 2018 the circularity of the world economy was estimated at 9% indicating considerable possibilities for developing more material flow which will subsequently bring substantial environmental and socioeconomic gains. (Berg, Antikainen, Hartikainen, Kauppi, Kautto, Lazarevic, Piessik and Saikku, 2018.)
Figure 1 below shows the vision of circular economy which offers boundless scenarios.

FIGURE 1. Vision of Circular Economy: Endless possibilities (Ellen MacArthur Foundation, 2017).

This chapter will seek to explain different circular economy concepts and circularity in industrial zones with a focus on industrial symbiosis and synergy. Also, this chapter will dive into Eco-industrial parks, types and some examples around the world.

2.1 Circular economy concept

Since the 1970s, the concept of circular economy has been deliberated and its feasible applications and industrial processes have gained ground. Lately, circular economy has seduced policy makers and the main companies on the global stage. The Ellen MacArthur Foundation and the McKinsey Company published a report which appraises the possible gains of a changeover to circular economy for the 2012 World Economic Forum in Davos. (Waulelet, 2018.)

Circular economy transcends the reduction of negative impacts of cradle to grave approach of handling waste. Circular economy identifies with a core shift which develops long-haul flexibility, hatch businesses and economic, environmental and social benefits. (Ellen MacArthur, 2017.) There exists no clear-cut origin of the concept of circular economy. The concept has been a product of different schools of thought from several authors. The global concept of circular economy had been shaped by the following schools of thought according to the Ellen MacArthur foundation. Figure 2 below can be described as circular economy in a diagram.

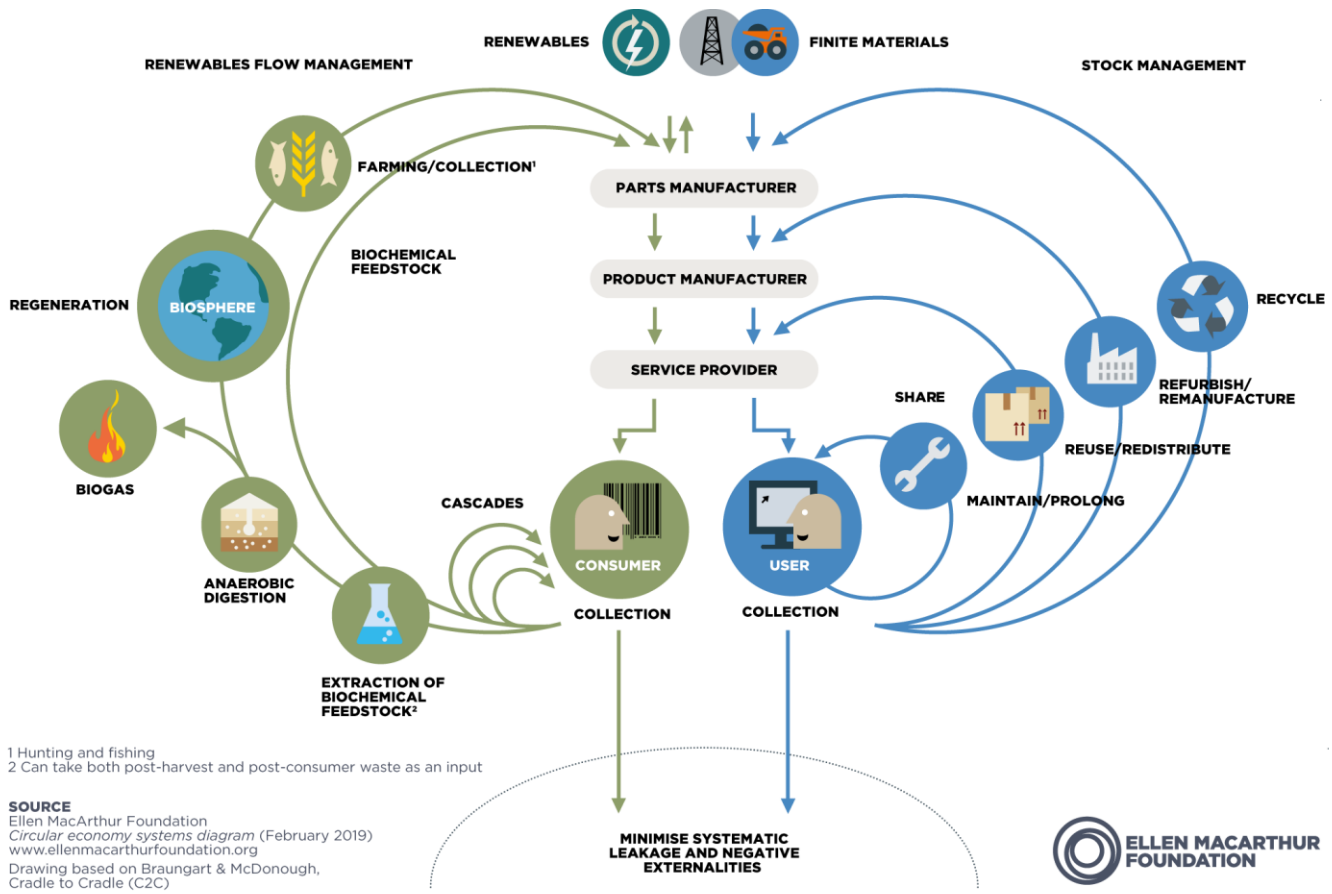


FIGURE 2. Circular economy system diagram (Dittrich-Krämer, Clauss, Kormann, Kicherer, Krüger, Shtirkova, Alexander, Pierce, Linder, Naber, Chavin, Dilkes-Hoffman, Durand, Surun, Sharma, Marchese, Gubelmann-Bonneau, Tryjefaczka, Hoffman, Uolamo, 2019).

2.1.1 Perfomance economy

In 1976, the European union accredited the research report *the potential for substituting manpower for energy* which was a vision of an economy in loop (circular economy) and its possible impact on employment creation, waste prevention, economic viability and resource saving. It was first elaborated by the Swiss architect Walter Stahel with Geneviève Reday as co-writer. (Waulelet, 2018; Ellen MacArthur, 2017.) This report highlighted that to substitute manpower with energy, product-life extension was the best plan. Stahel's book *The Performance Economy* published in 2010, is the first to present eloquently the idea of a circular economy as indicated by the Ellen MacArthur Foundation in 2017. In this book, Stahel articulates that the growing high resource consumption accompanied by high waste production, increased public debt crowned by haunting unemployment and slow economic growth are limitations of the current industrial economy. According to Stahel, these limitations are expelled with performance economy strategies. Performance economy specifies on resource sufficiency over resource efficiency and the propagation of system solutions over product and manufacturing business models. (Waulet 2018, 10-11.)

2.1.2 Cradle to Cradle (C2C)

The concept was coined by Stahel in 1970. The development and certification process of the cradle to cradle designed was established by Michael Braungart a German chemist and visionary and Bill McDonough an American architect. This design was presented and elaborated in their books ‘‘Cradle to Cradle: Remaking the way we make things’’ (Braungart & MacDonough, 2002) and ‘‘The Upcycle: Beyond sustainability - design for abundance’’ (Braungart et al, 2014).

The concept of the cradle to cradle design is the creation of an industrial network propelled by the synergic tracking of optimistic economic, environmental and social objectives (Braungart, MacDonough, Bollinger, 2006). In Braungart’s 2002 book, a design model is presented with three principle derived from nature diagnostic of the model. The first principle presents everything as a primary material for another process. The second and third principle stipulates everything can be built, broken down and returned to the soil as biological nutrients or re-invented as high-quality material for novel products as technical nutrients without contamination. (Braungart et al, 2002.) Figure 3 below presents the difference between biological and technical cycles in the cradle to cradle design.

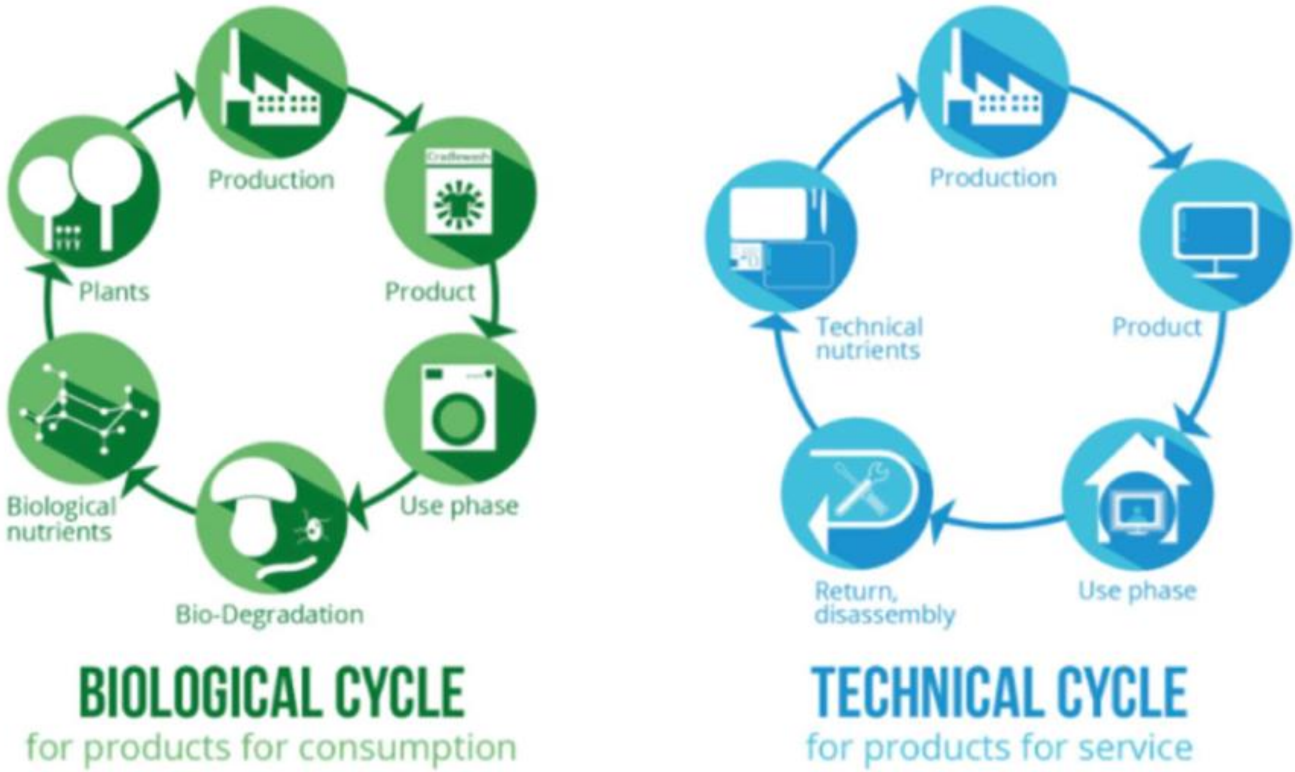


FIGURE 3. Distinction between biological and technical cycles in the Cradle to Cradle design (EPEA, 2017).

2.1.3 Biomimicry

Janin Benyus in her book Biomimicry: Innovation Inspired by Nature, defines biomimicry as a novel discipline which investigates natures most valued ideas and mimics these models and processes to solve human challenges (The biomimicry institute, 2017). An example of biomimicry will be studying a leave to invent a better solar cell (Ellen MacArthur, 2017).

The core principle of biomimicry is that nature has already offered solutions to most of the challenges the world faces. Biomimicry depends on three main guiding principles. Firstly, considering nature as a model where creation of innovative design models for products and services is inspired by nature’s form, processes and living ecosystem. Secondly, nature as a measure where ecological standards are used to evaluate sustainability of innovation and models. Finally, nature as a mentor where nature is seen as a source of knowledge to solve our problems rather than a honeypot of what it can offer the world. (Ellen MacArthur, 2017.)

Benyus (2002) insisted that in modelling natures inspired solutions we have to think about the whole system from production, transportation to delivery ensuring a forest-like economy. Since all processes in nature are low energy, material efficient and occur at ambient temperature, companies can use biomimicry to build technological models, industrial processes and systems which are more energy and material efficient and less toxic. (Waulet 2018, 20.)

2.1.4 Industrial Ecology (IE)

IE also assisted in the development of the circular economy notion. The fact that human life was inflicting adverse environment impacts propagated the emergence of industrial ecology in 1970s. Industrial ecology came as a contradiction of industrial system existing separate from the environment. (Waulet 2018, 2.)

Industrial ecology is the study of material and energy flows through industrial systems, regulations and the interaction of these systems with the biosphere (Erkman, 2001). The essence of IE is to create a closed loop with by-products acting as inputs in other processes eliminating waste streams. (Ellen MacArthur, 2017.)

For industrial ecology to come to fruition four principles must be considered. Firstly, value must be made of waste and by-products efficiently. With reference to food chain processes, connections of resources and waste applications in industrial ecosystems must be conceived. This is to ensure all the residues for other enterprises (via eco-industrial parks). Secondly, dispersion related losses must be minimized. Global consumption of goods and services has a high adverse effect on the environment than the actual production processes of these goods and services. Hence, the philosophy of diminishing dispersion or phasing out harmful effects need to be part of novel goods and services designed. Thirdly, dematerialization of the economy with the reduction of matter and energy while ensuring comparable services are provided, as the main goal. The dematerialization process can be relative where productivity is increased with a given resource or absolute dematerialization where the flow of matter in an industrial system is minimized infinitely. Finally, alternative sources of energy must be explored to reduce the dependence on fossil hydrocarbons. (Erkman, 2001.)

2.2 Circularity in industrial parks

The idea of circularity in industrial parks revolves around producing goods and services while diminishing the consumption and waste of raw materials and energy. An industrial park can be defined as a plot of land that has been set aside, planned and dedicated for industrial development. (Pauceanu, 2016.) This section will look at industrial symbiosis in industrial parks and eco-industrial parks.

Industrial symbiosis is the process by which side streams and by-products of a production chain become raw materials for another. This promotes sustainability and circularity or circular economy in a system. (Interreg-IPA CBC, 2018.) The industrial symbiosis in the industrial park envisages a relationship which can be compared to living organisms entertaining a mutually beneficial relationship. In a similar relationship between industries in the park, problems like increase in waste, waste treatment cost and waste disposal cost are minimized. (Neves, Godina, Azevedo, Pimentel, Matias, 2019.) The finality of industrial symbiosis is the fading of the carbon footprint of companies, accompanied by economic and social benefits.

According to the United Nations Industrial and Development Organization (UNIDO) an eco-industrial park is a network of enterprises seeking to maximize social, economic and environmental benefits through synergy in managing environmental and resource issues in one common space. The definition above shows eco-industrial parks among their numerous advantages promotes circular economy practices and resource efficiency. (UNIDO, 2020.) EIP share common characteristics. The typical facets associated with all EIPs are firstly, co-location and proximity as EIPs have an assemblage of companies close to resource recovery and recycling facilities. Secondly, shared by-products where the waste and by-products of one company serve as the production material for another company. Finally, insistence on cleaner production throughout the production chain. There are other characteristics usually common to EIPs such as ecological design, collaborative financial system, research and development activities and sharing of services. (Macauley, 2013.)

2.2.1 Types of eco-industrial parks

When considering Eco-industrial parks, four main categories exist. First is the resource recovery park which represent a collection of reuse, recycling and composting processing, production and retail enterprises marketing materials and products in one location. Second is the zero-emission park with a group of businesses in one common area in synergy to reduce and eliminate emissions and waste. Third is the eco-industrial and resource recovery park. Finally, is the virtual eco-park which involves companies in different locations working together to reduce their impact on the environment. (Making lewes, 2014.)

2.2.2 Examples of Eco-industrial park models

Kalundborg eco-industrial park model in Denmark is an advanced evolution of industrial symbiosis with about 18 visible connections. The 6 key local players that have made this symbiotic relation possible are: Asnaes power station, SK Power's 1350-megawatt power plant; a large oil refinery operated by Statoil A/S; Novo Nordisk Novozymes A/S; Gyproc Nordic East; A-S Bioteknisk Jordrens; and the municipality of Kalundborg. Novo Nordisk Novozymes A/S is a Danish pharmaceutical and a Danish biotechnology company. Nordic East is a plasterboard manufacturer and A-S Bioteknisk Jordrens is a soil remediation company. There exist other companies within and outside the Kalundborg municipality that make use of the by-product to raw material and energy exchanges. (Ehrenfeld & Chertow, 2002.) At the center of this model is the Asnaaes Power station (largest in Denmark). 80 per cent of previously discarded energy by Asnaes power plant is exported. Since 1981 3500 oil fueled residential furnaces have been phased out by heat supplied from the power plant through a series of underground pipes to the municipality. (Ehrenfeld et al, 2002.) Figure 4 below can better show the symbiotic flow in the Kalundborg EIP model.

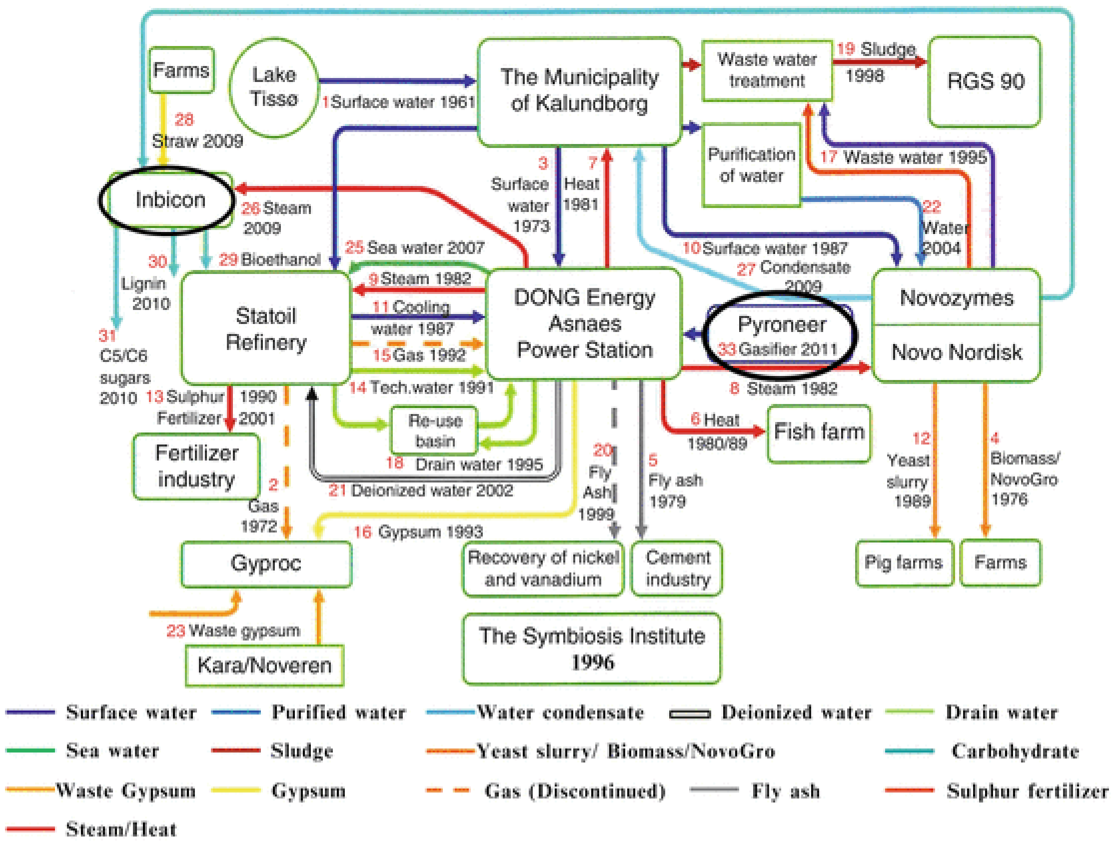


FIGURE 4. Industrial symbiosis at Kalundborg, Denmark (Global lamp index).

Through the years the Kalundborg model has proven dynamic and adaptive. For example, the Satoil's sulphuric acid production stopped, projects such as the Asnaes steam powered greenhouses never matured and there is constant monitoring and evaluation of new projects. (Ehrenfeld et al, 2002.) Table 1 shows the gains made as a result of the symbiotic system at Kalundborg.

TABLE 1. Waste and Resource savings at Kalundborg (Ehrenfeld et al, 2002)

Annual resource savings through interchanges
Water savings
Statoil: 1.2 million cubic meters
Asnaes: total consumption reduction 60%
Fuel savings
Asnaes: 30000 tons of fossil fuel by using Statoil fuel gas
community heating via steam from Asnaes
Input chemicals/products
fertilizer equivalent to Novo Nordisk sludge (about 1300 tons nitrogen and 550 tons phosphorus)
97000 cubic meters of solid biomass (NovoGro 30)
280000 cubic meters of liquid biomass (NovoGro)
commercial fertilizers for 20000 hectares of farmland using Statoil sulfur
170000 tons of gypsum
recovered vanadium and nickel
Wastes avoided through interchanges
50000–70000 tons fly ash from Asnaes
scrubber sludge from Asnaes
2800 tons sulfur as hydrogen sulfide in flue gas from Statoil (air)
water treatment sludge from Novo Nordisk (landfill or sea)
380 tons of sulfur dioxide avoided by replacing coal and oil (air)
130000 tons carbon dioxide avoided by replacing coal and oil (air)

Harjavalta Eco-Industrial Park in Finland is an example which shows the gradual transition from industrial parks to eco-industrial parks in Finland. Harjavalta is a mining town with Boliden Harjavalta copper and Outokumpu Metals Group nickel smelters being at the heart of this town. There are at least 14 companies in the area and about 1000 employees. The main companies in the area are Boliden Harjavalta Oy, Outokumpu Metals Group (OMG) Harjavalta Nickel Oy, Porin Lämpövoima Oy, Oy Aga AB (AGA), Kemira, the town of Harjavalta. The main exchanges in this EIP are extra energy made into electricity and high temperature steam supplied to the Harjavalta community and processing plant and other flows occur in this park like gypsium, sulphuric acid, Ammonia. (Saikku, 2006.)

Application and cascading the energy captured from copper and nickel flash processes is one of the ultimate details of the Harjavalta EIP. Some advantages of the symbiosis in this EIP include firstly, employment, intellectual capital and international approval. Secondly, great environmental advances from improved raw material efficiency. Thirdly, improved product and raw material diversity which diminishes the use of primary resources, maintains below board the overuse of non-renewable material and boost the method of tackling global environmental issues of sustainability. (Heino, 2012.)

Figure 5 below will show the flow of material and energy in the Harjavalta EIP.

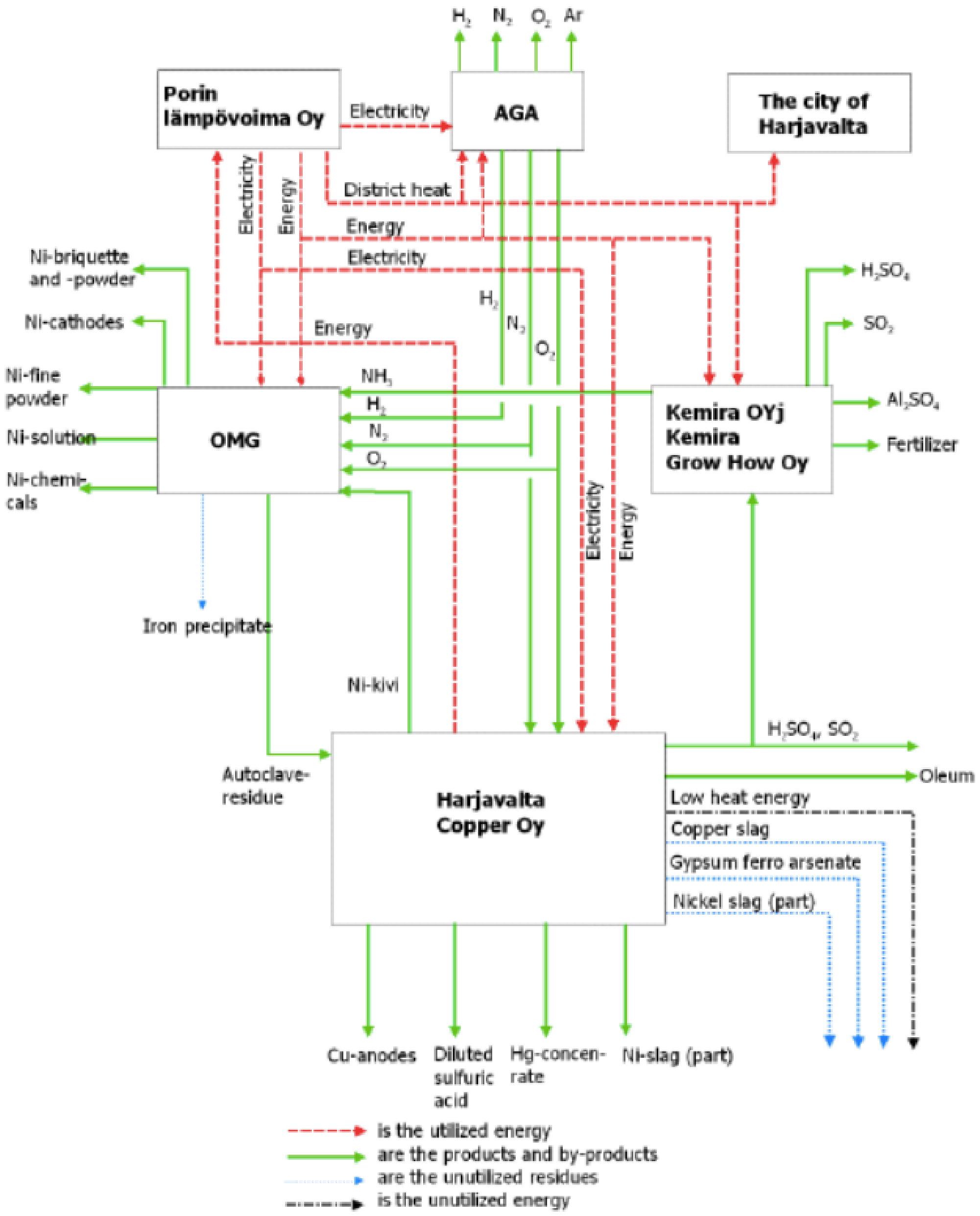


FIGURE 5. Material and Energy flow in the Harjavalta eco- industrial park (Heino & Koskenkari, 2004 and Heino, 2010).

3 MEASUREMENT OF CIRCULARITY

The effectiveness of the transition from a linear economy to a circular economy and the effective implementations of circular economy principles can be investigated with a series of indicators which is going to be the focus of the first part of this chapter. The second part will evaluate the socio-economic and environmental impacts of the circular economy transition.

3.1 Circular economy indicators classification framework

As earlier mentioned, to control the transition to circular economy at various systemic levels, scholars, governments, industrialist and the world are in accord for the application of CE-oriented measuring tools resulting in the development of a wide range of circularity indicators (Cindicators) in recent years. It is vital to know what each indicator measures to apply them effectively. This is because of the presence of different definitions to CE. There exist more than 55 sets of Cindicators modelled by governmental agencies, intellectuals, and consulting companies and these Cindicators cover different purposes, scopes and potential applications. This section will discuss some of the major Cindicators with the objective to improve, monitor and communicate on CE performance. (Saidani, Yannou, Leroy, Cluzel, Kendall, 2019.)

3.1.1 What indicators measure in CE

One way to clearly define what an indicator measures in CE is understanding and adopting a consensus on the definition of CE. There is no definition for CE that covers all aspects of the concept thus, focusing on one definition to pinpoint what indicators measure in CE is limited and excludes other CE considerations. The approach used in this paragraph is establishing parameters which cover various circular economy approaches and as markers two definitions representing CE in a specific sense (sensu stricto and broader sense (sensu lattu). (Moraga, Huysveld, Mathieux, Andrea, Alaerts, Van Acker, de Meester, Dewulf, 2019.) The sensu stricto definition of CE is differentiated from linear economy by two aspects: slowing resource loop through Long-life goods and product-life postponement models, and closing resource loops through recycling; also, a third aspect resource efficiency focuses on using fewer resources per product (Bocken, de Pauw, Bakker & van de Grinter, 2016). On the other hand, according to Murray et al. (2017) sensu lattu definition of CE has a broader scope where CE as an economic model emphasizes sustainability and effects of CE strategies on the environment, economy and society.

A second hypothesis or rational is grouping CE strategies according to common aspects. Based on hierarchical ladder CE strategies can be categorized into 6 different groups according to their effort to preserve functions of goods and services provided by circular business models, products itself through lifetime increase, components through reuse, recover and repurposing of parts, materials through recycling and downcycling, embodied energy through energy recovery at incineration facilities and landfills; also, measure linear economy as a baseline. (Moraga et al, 2019.)

A third rational is measuring according to the CE definition and CE strategies. The impact of circularity on the environment can be direct and indirect and its evaluation can be based on direct and indirect indicators. This rational classifies CE indicators into 3 measurement types based on the first two rationales discussed earlier. The three measurement types are, direct CE with specific strategies where indicators can concentrate on one or more detectable CE strategy e.g. durability is specific to products, direct CE with non-specific strategies where indicators focus on more than one strategy and identifying the exact strategy is difficult e.g. water withdrawal and Indirect circular economy where indicators may check aspects of CE strategies but with the use of additional methods to access CE. (Moraga et al, 2019.)

3.1.2 How indicators measure CE

One of the processes involves measuring scopes according to Life Cycle Thinking (LCT) and modelling levels. CE is involved in many levels of the production and consumption process hence indicators may apply a life cycle approach (Moraga et al, 2019). LCT is the capacity to look beyond production, manufacturing and consumption of products and services to involving environmental, social and economic impacts, also including relationships with sustainability (Life Cycle Initiative, 2020). Figure 6 below shows a typical life cycle process of a product. In each life cycle stage, there is the possibility to reduce resource consumption and optimize product performance which improves the products circularity.

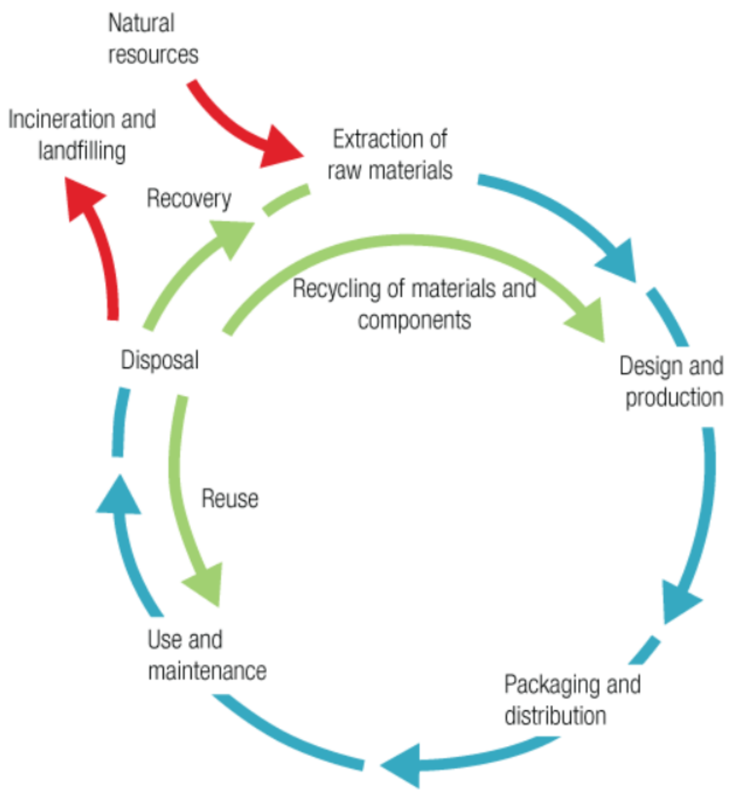


FIGURE 6. A typical product life cycle diagram (Life cycle initiative 2020).

Indicators evaluating CE can be grouped into three measurement scopes considering their LCT approach and modelling levels. These scopes are: Scope 0, where the LCT approach is not involved in the indicators measurement of physical properties from the technological cycles e.g. Recycling rate. Scope 1, where full or partial LCT approach is involved in the indicator's measurement of physical properties from the technological cycle e.g. Reusability/Recyclability/Recoverability (RRR).
Scope 2, where the indicator measures the environmental, economic and social effects from the technological cycle in a cause/effect chain modelling e.g. Reusability/Recyclability/Recoverability (RRR) benefit rate. (Moraga et al, 2019.) Figure 7 will show a proposed classification of the three scopes discussed above.

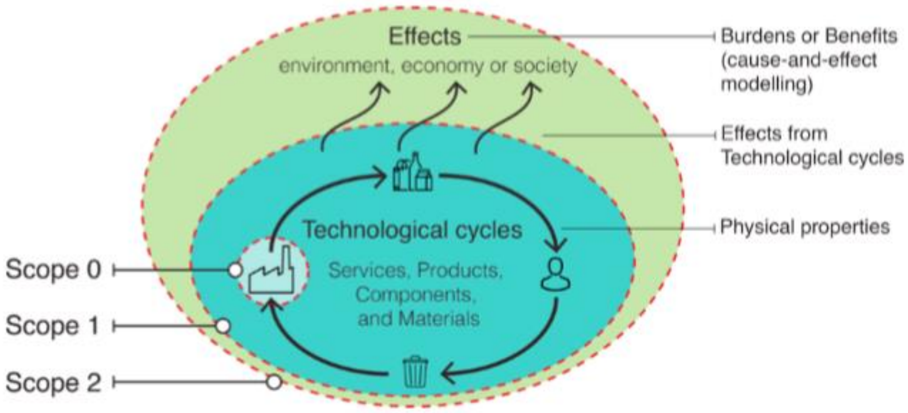


FIGURE 7. Proposed classification for the three measurement scopes from CE indicators (Moraga et al, 2019).

Secondly, indicators can measure CE by making use of the implementation scale. There exist different CE implementation scales. Some review outlines (Ghisellini, Cialani, Ulgiati, 2006; Kirchherr, Reike, Hekkert, 2017) identify three main CE implementation scales. These scales are, micro identifying a product, consumer, or company; meso identifying an industrial symbiosis or and eco industrial park; and macro identifying a city, region or nation. (Moraga et al, 20019.)

Thirdly, indicators can measure CE by using equation types of indicators. Globally indicators are variable informing for valuable decision making. Variables can be quantitative or qualitative. Indicators can be individual variables or a function of variables e.g. ratio (number apropos a baseline value), index (an individual number from a combination of two or more variables), or the outcome of a compound simulation model. The reference line indicated above can be an unclassified target baseline or a standard with quantitative (specific) and qualitative (non-specific) targets. (Moraga et al, 2019.) Based on the information above, figure 8 presents the classification model for CE indicators

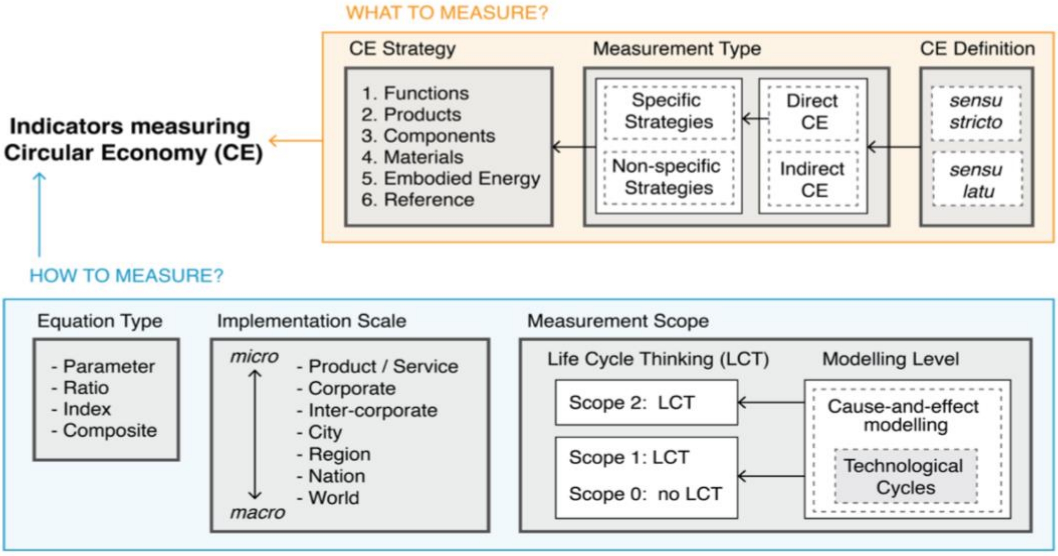


FIGURE 8. Classification framework for CE indicators (Moraga et al 2019).

3.2 Exposing the classification scheme: Micro scale indicators

To perform this diagnosis 20 micro scale indicators and fourteen documents were investigated and figure 9 designed. The indicators used for this illustration cover the measurement type of Direct CE with specific strategies. The list of Indicators: eDiM (ease of Disassembly metric); CR (old scrap Collection Rate), RR (Recycling process efficiency Rate); EOL-RR (End of Life Recycling Rate); RIR (Recycling Input Rate); OSR (Old Scrap Ratio); Longevity; MCI (Material Circularity Indicator); PLCM (Product-Level Circularity Metric); CPI (Circular economy Performance Indicator); CEI (Circular Economy Index); VRE (Value-based Resource Efficiency); EVR (Eco-cost value ratio); NTUM (Number of Times of Use of a Material); CIRC (Material Circularity Indicator CIRC), TRP (Total Restored Products), LMA (Lifetime of Materials on Anthroposphere); Displacement; SCI (Sustainable Circular Index); GRI (Global Resource Indicator). (Moraga et al, 2019.)

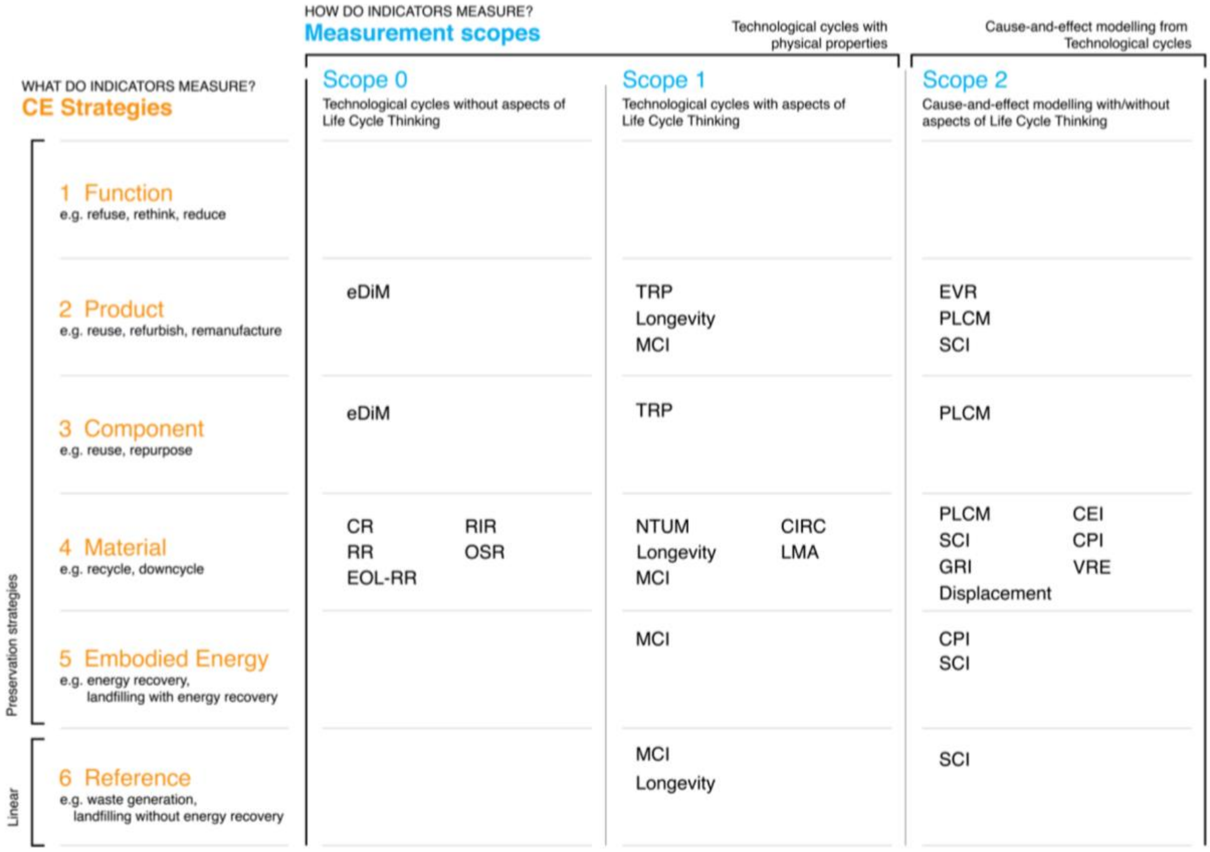


FIGURE 9. Indicators measuring CE at the micro scale (Moraga et al, 2019).

3.2.1 Overview of micro scale indicators

Since the indicators used can segregate the computed strategy, the assessment type of all investigated indicators is direct access with specific strategies. From figure 9, many indicators analyze strategy 4 (Preservation of material) when the CE strategy is taken into consideration. When studying the measuring scope, it is noticed that many of the indicators fall into scope 1 and 2 which consider LCT approach partially or in full. An indicator like MCI in scope 1 examines more than a strategy of technological cycles. LMA and NTUM focus on recycling and downcycling to explain the time spent by materials in a system (residence time); hence only strategy 4 is analyzed and LCT approach is attained. Strategy 1(preservation of function) is not measured by any examined indicators (Moraga et al, 2019.)

3.2.2 Analysis of CE indicators

From the list of analyzed indicators, no indicator clearly measures function. Some indicators try to apply a combination of quantitative (for example, eco cost value ratio) and qualitative (for example circular transition framework) indicators but still the preservation of function is not distinctly illustrated. Life cycle analysis (LCA) and material flow analysis (MFA) may preserve function but indicators are still vital. (Moraga et al, 2019.)

Indicators evaluate strategies on products and components in different ways, but 2 pathways are remarkable: the evaluation of quantity and quality. Detectable properties that are not consumer or market related can be reported by indicators evaluating quantity. For example, a material flow analysis (MFA) based indicator, Total Restored Product (TRP) at the end-of-life (EoL) reports on the products reused, refilled, refurbished, redistributed and remanufactured. On the other hand, properties influenced by the consumer or markets, such as period or economic value is reported by indicators evaluating quality. This can also be called the circularity metric e.g. the product-level circularity metric (PLCM). (Morega et al, 2019.)

$$\text{PLCM} = \frac{economic\ value\ from\ recirculated\ flows}{total\ economic\ value} \tag{1}$$

Longevity indicator also measures quality. It reports the duration of a material in a product by using lifespan approximations from data records and professionals' estimations. On like longevity indicator, identical products with different lifespans can have the same PLCM outcomes. Longevity indicator has a problem with the uncertainty posed by various consumer attitude. In the present, the measure of quantity may be more decisive, but the measure of quality requires more consideration of CE indicators and may show the impact of consumer attitude. (Morega et al, 2019.)

3.3 Socioeconomic and Environmental impacts of Circular economy transition on a macro scale

Society constantly struggles with the satisfaction of human needs and the protection of resources and biological diversities. There has been a lot of research on circular economy with respect to business models and new technology. When it comes to a macro level (national, multinational and global), there is void and potential research in the socioeconomic and environmental impact of a transition to CE. A macro level research on the implementation of CE helps develop policies for a cost-effective CE transition. (Glenn, João, & Arnold, 2020.) In 2013 the Ellen McArthur Foundation proposed the circularity interventions which represented a collective of measures that improve resource use and material validity inside an economy. Circularity interventions can be classified into four types: ¨closing supply chains, residual waste management, product lifetime extension and resource efficiency¨.

To understand the socioeconomic and environmental impact of CE transition on a macro level a study was conducted with focus on three key indicators' Gross domestic product (GDP), employment (job creation) and carbondioxide (CO_2) emissions representing macroeconomics, social and environmental impacts. Various circular economy scenarios (CESs) were ran through these indicators and their impacts on these indicators analyzed. 27 relevant publications tackling 324 CESs were eligible for meta-analysis because they met 4 criteria. Firstly, at least one circularity intervention type. Secondly, at least one macroeconomic, social and environmental indicator. Thirdly, the macrolevel impacts were assessed with structural, macro-economic or integrated assessment models. Finally, possible scenarios were analyzed from 2020-2050 in comparison with a respective standard scenario. (Glenn et al, 2020, 3.)

In the meta-analysis 3 rules were followed: numerical values focusing on GDP, job creation and CO_2 emissions of different CESs were quoted and normalize to compare with other CESs. The CESs were clustered under 2 groups (moderate and ambitious scenarios) and a statistical investigation was done with an appraisal of correlations between the indicators. A study accounting for more than two scenarios makes those scenarios ambitious because their effect on GDP, job creation and CO_2 emissions when compared with Business As Usual (BAU) scenario was biggest. Any other scenario besides the BAU and ambitious scenario are designated moderate. (Glenn et al, 2020, 3.)

CESs represent rational and systematic descriptions of prospective impacts if circularity interventions proposed by Ellen MacArthur (2013) were realized. To understand the impact of a transition based on the possible CESs, CESs with numerical values of GDP, job creation and CO_2 emissions were compared to business as usual (BAU) scenarios between 2020 to 2050. In each of the 27 publications used, BAU scenarios were computed by studying GDP trends, population growth, energy and material consumptions based on projections from the United Nations Statistics Division, the International Energy Agency, Eurostat, or national statistical offices (UNEP 2017, 55-108.)

To compute the difference between a CES and a BAU scenario the following mathematical computation was used:

$$\Delta CES_{i,t} = \frac{CES_{i,t} - BAU_{i,t}}{BAU_{i,t}} \times 100, \tag{2}$$

where $\Delta CES_{i,t}$ represents the changes in indicator i (i.e. GDP, job creation, or CO2 emissions) for year t (from 2020 to 2050), $CES_{i,t}$ and $BAU_{i,t}$ represent the absolute value of the circular economy scenario and the business-as-usual scenario for i in t, respectively. $\Delta CES_{i,t}$ was used as an indicator to compare the macroeconomic, social and environmental impacts of circularity interventions across the literature (Glenn et al, 2020).

To study the pathway of macro-economic, social and environmental impacts, a plot of changes in GDP, job creation and CO_2 emissions from 2020-2050 was done as shown in figures 10, 11 and 12 below. The median, minimum and maximum values, and the interquartile range as a means of statistical dispersion was also computed. To investigate if the changes in GDP, job creation and CO_2 emissions was negative or positive, a classic Pearson product moment correlation coefficient (r) was used. A win-win situation for the indicators depends on the sign of correlation coefficient (r). A positive r ($0 < r \leq 1$) in the interaction between GDP and employment is a win-win because of the simultaneous increase in jobs and GDP. When considering macroeconomics and environmental impacts, a negative r ($-1 \leq r < 0$) representing an increase in GDP and a decrease in CO_2 emissions is considered a win-win. (Glenn et al, 2020.)

3.3.1 Path of changes of GDP, job creation and CO_2 emissions for 2020-2050.

Figures 10, 11 and 12 below will show an appraisal of the macroeconomic, social and environmental impacts of a CE transition based on the 27 studies selected with GDP, job creation and CO_2 emissions as metric changes. Figure 10, 11 and 12 displays a scope of changes in GDP, job creation and CO_2 emissions determined from the 27 selected publications with the results presented in relation to each publication's BAU scenario as indicated in equation (1) above. In these figures, blue crosses indicate the values of moderate scenarios in each study. Green dots indicate the values of ambitious scenarios in each study. Blue and green dashed lines denote the median of moderate and ambitious scenarios in each year, respectively. Light blue and green areas denote the range between the maximum and minimum values for moderate and ambitious scenarios per year, respectively. (Glenn et al, 2020.)

In figure 10, the pathway of ambitious CESs for GDP consist of a bigger range of values from -0.1% to 14.0%. An increase in the median value from 0.2 % in 2020 to 3.0% in 2050 implies a positive impact of ambitious CESs on GDP. In contradiction, moderate CESs shows a small scope of impacts on GDP as it shows a very small change over time from a median of 0,0% in 2020 to 0.7% in 2050. (Glenn et al, 2020.)

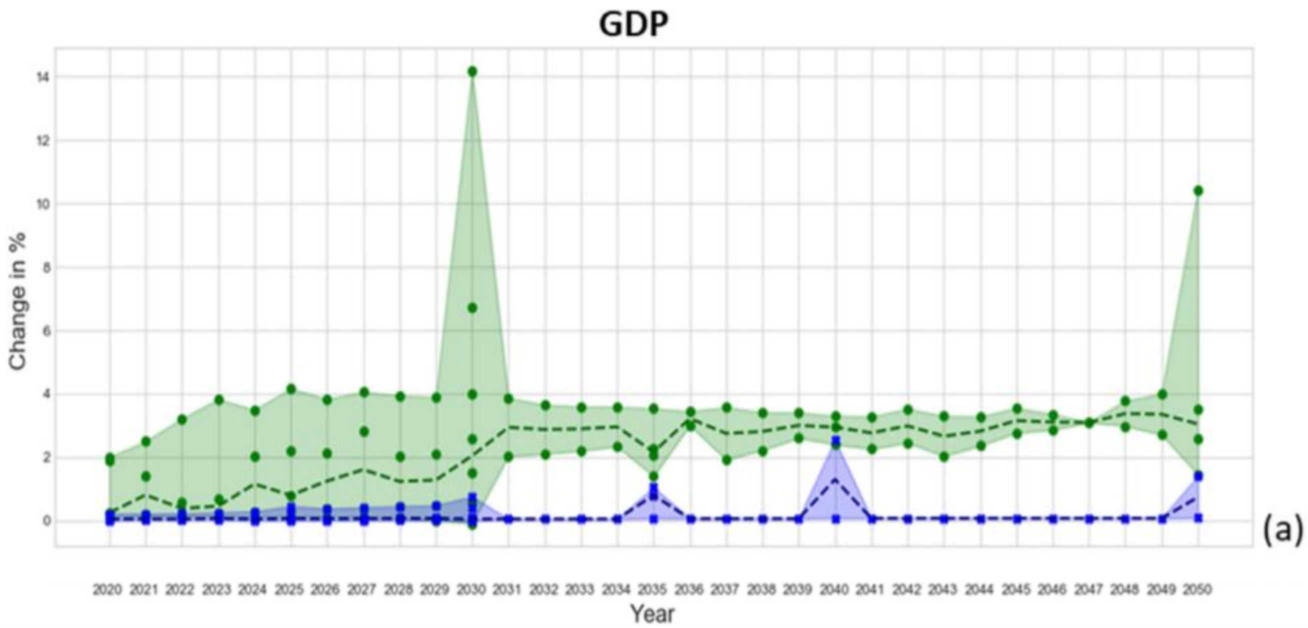


FIGURE 10. Range of changes in GDP from 2020 to 2050 as estimated in the selected studies (Glenn et al, 2020).

In figure 11, the increase in job creation from a median of 0.9% in 2020 to 4.1% in 2050 show the positive impact of ambitious CESs on employment. From 2030 to 2050 we only have 2 ambitious scenarios from two sources and moderate scenarios from 2 other sources hence, limited CESs to obtain a better assessment of employment within the above-mentioned time period. (Glenn et al, 2020.)

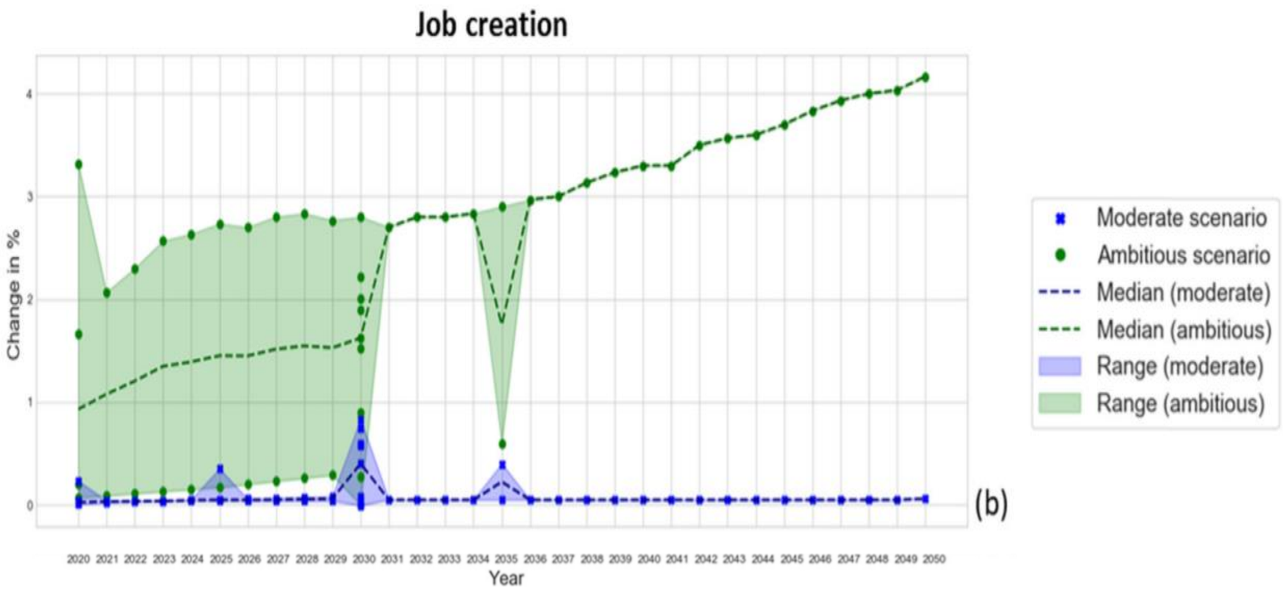
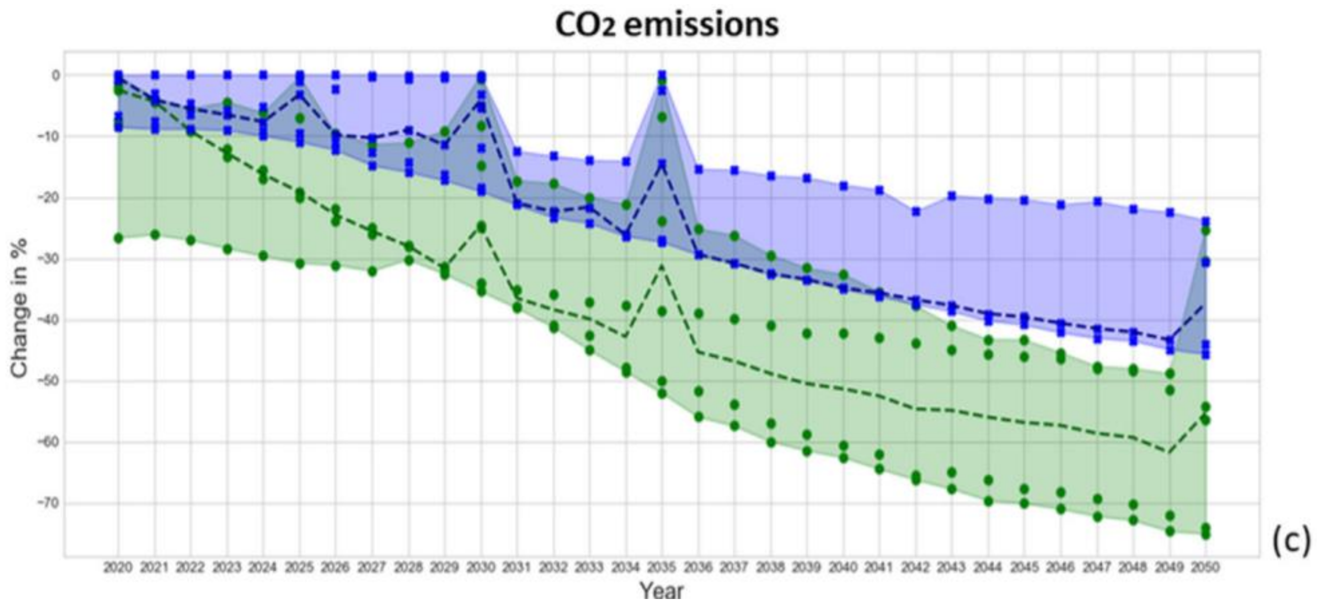


FIGURE 11. Range of changes in job creation from 2020 to 2050 as estimated in the selected studies (Glenn et al, 2020).

Figure 12 analyses the impact of CESs on CO_2 emissions. Ambitious and moderate scenarios both show a decrease in CO_2 emissions. In ambitious scenarios, the decline spans from -0.1% to -71.0% with a median value range of -2.5% in 2020 to -55.3% in 2050. In moderate scenarios, the CO_2 emissions vary from 0.1% to -45.6% with an average value of -0.4% in 2020 to -37.4% in 2050. (Glenn et al, 2020.)



Range of changes in CO2 emissions from 2020 to 2050 as estimated in the selected studies

The finality of circular economy on GDP, job creation and CO_2 should be a win-win relation. Table 2 below portrays the correlation analysis of 3 macro indicators (GDP, job creation and CO_2 emissions) in 2030 with r as a measure of relation between the indicators. This enables the determination of a win-win-win in terms of macroeconomic, social and environmental impact.

TABLE 2: Correlation between GDP, job creation and CO_2 emission in 2030 (Glenn et al, 2020).

Correlated variables	Pearson correlation coefficient (r)	Outcome
GDP & Job	0.65	Win
GDP & CO_2	−0.60	Win
Job & CO_2	−0.58	Win

As indicated on the table above a r of 0.65 indicates a positive relation between GDP and job creation. This implies that if a CES results in a bigger GDP than another CES then it is expected to also lead to the creation of more jobs. The relation between CO_2 emissions and GDP is negative (r = -0.60), likewise the relation between CO_2 emission and jobs (r = -0.58). This means if a CES has a positive impact on GDP and job creation, it is expected to reduce emissions. Based on the Pearson correlation coefficients above we note that a circular economy transition could lead to a win-win-win situation for macroeconomic, social and environmental impacts. (Glenn et al, 2020.)

4 CASE STUDY: KOKKOLA INDUSTRIAL PARK (KIP) FOCUS ON BOLIDEN

The KIP is a 700 hectares expanse of land encompassing eighteen industrial plants and about sixty service companies to assist the production factories. KIP is the largest ecological community for inorganic chemical companies in Northern Europe. (circhubs, 2018.) This chapter will delve into circularity in KIP specifically in Boliden, and which indicators are involved to evaluate the CE process in this park.

4.1 Circularity in KIP

The industrial synergy existing in KIP represents one of the best in Europe and it advances the CE objectives of this park. The main symbiotic relationships in the park are based on energy and material flow and this is made easy by the fact that the companies are inherently connected to each other. For example, the Boliden zinc smelter produces excess heat and steam which help in providing electricity and heating up the Kokkola municipality. There is also the Boliden sulphuric acid plant which is a source of raw material to other plants in the KIP. Figure 13 below shows the symbiotic relationship existing in the KIP area. (New Boliden, 2021.)

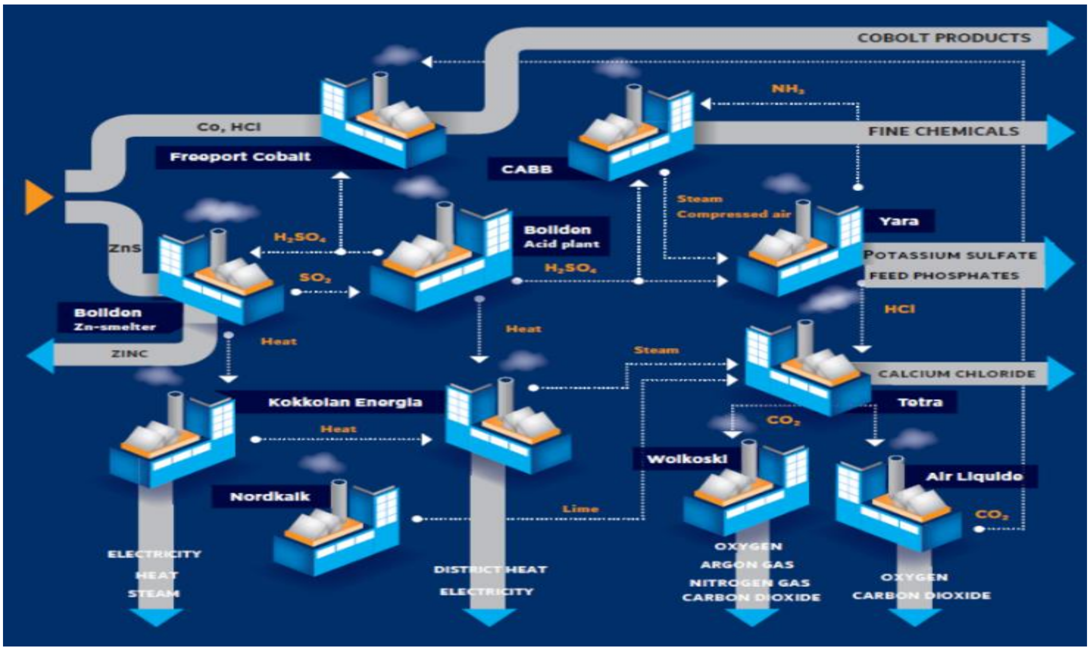
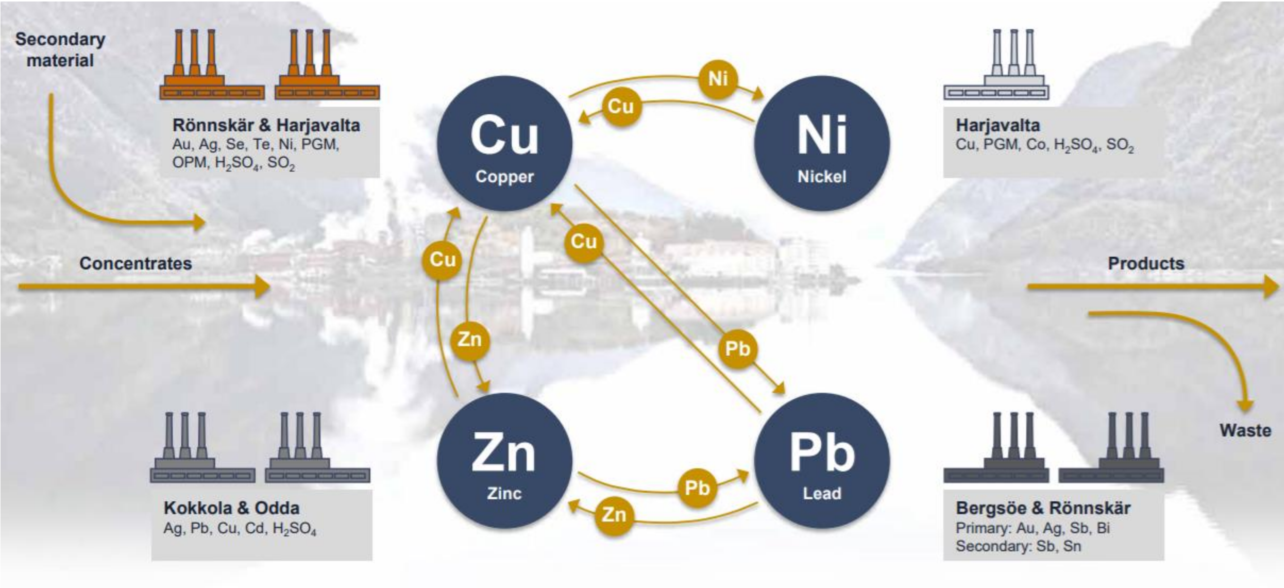


FIGURE 13. Symbiosis in the Kokkola Industrial Park. (New Boliden, 2021.)

To put things in context, in 2017 Boliden produced 320 000MWh of steam an equivalent of the energy used in heating 16 000 households. This steam was used to supply municipal heating, electricity and low-pressure steam to some plants in the KIP. In the same year, 125 000 MWh of excess heat was generated from the Boliden sulphuric acid plant, enough to provide for about 6000 homes and some KIP buildings. Boliden produces a high quantity of carbon free energy as the roasting process in the smelter uses zinc concentrates for fuel. This excess steam used to generate electricity and supply heating to homes reduces the cost of buying carbon dioxide allowances from the emissions trading market. Comparing with other zinc smelters around the world, Boliden's carbon footprint is low (1,910 kg CO_2e/t Zn). This puts Boliden amongst the most efficient zinc smelters around the globe. New Boliden, 2021.)

There exists a win-win industrial synergy in the KIP. The sulphuric acid used by other plants in the KIP is produced in the Boliden sulphuric acid plant and supplied through a network of pipelines. This means of supply helps reduce the carbon footprint involved in the transportation of this product. Same way, the sulphur dioxide generated from the zinc smelter is supplied to the sulphuric acid plant. Around the KIP carbon dioxide and other air gases are important by-products that are raw materials for other processes in the KIP (one man's waste another's raw material). (New Boliden, 2021.) Boliden operates mines and smelters across Europe, and this has a significant impact on CE as there exist the exchange of by-products between their various operations. Figure 14 below shows circularity in Boliden smelters.



Boliden smelters circular economy (Boliden annual and sustainability report 2020, 27).

4.2 Boliden`s environmental performance

Boliden`s approach to circular economy is intentional across all of it mines and smelters across Europe. Detail reporting is done every year on its environmental performance. Boliden is actively involved in finding efficient methods in the extraction and recovery of metals from side streams. 4 million lead acid batteries (50 metric kilotons Pb/year) from the automotive sector is recycled annually by Boliden. Approximately 2 million mobile phones worth of electronic material (120 kilotons/year) are recovered daily. These recycled metals account for about 11% of Boliden`s metals. (Boliden Annual and Sustainability report 2020, 34.)

One other area of great interest for Boliden is the reduction of fossil carbon dioxide emissions and intensity with an equivalent of 615 kilotons of carbon dioxide emitted directly and indirectly from the smelters. As earlier indicated with the specific example of the Boliden unit in Kokkola, energy efficiency is very important for all the Boliden units. The better management of the surplus heat from smelters curtails the carbon dioxide emissions. In the course of the year 2020, 751 GWh was reused in the smelters and 851GWh was delivered for district and municipal heating. (Boliden Annual and Sustainability report 2020, 34.) These few points are an indication of the company`s commitment to the transition to an effective circular economy system.

5 CONCLUSION

This project started with the aim to elaborate on the circular economy journey and strategies of the Kokkola Industrial park (KIP) with a keen focus on Boliden. Secondly, the chapter will look at the circular economy situation around the globe and what strides have been made. This work was carried out mainly through a literature research approach. The information was mainly sourced through journals, articles and websites. The biggest challenge was sourcing for information specific to the Kokkola Industrial Park as there have not been a lot of park specific documentations on CE online. The Covid outbreak also did lead to cancellation of the site visit.

To understand the CE situation around the world entailed understanding the different circular economy concepts that traced a roadmap for the transition to circular economy. Stahel in performance economy highlights the importance of resource sufficiency over resource efficiency and the propagation of system solutions over product and manufacturing business models. Another CE concept cradle to cradle whose methodology was developed by Michael Braungart and William McDonough with the simple understanding that waste is equal to food. There is also the biomimicry concept which Janine Benyus defines as a novel discipline which investigates nature's most valued ideas and mimics these models and processes to solve human challenges. The final concept examined was the industrial ecology which focuses on material and energy flow through industrial systems and their interactions with the environment.

Industrial park and eco-industrial parks stand out as one of the best transitions to a CE. The idea of one man´s waste or excess is another`s input makes these parks ideal for industries. The case studies examined show the shared value existing in the industrial and eco-industrial parks. Table 1 shows the amount of waste and resource savings at Kalundborg. Developing an industrial park is not enough as the circular economy objectives must be drawn and implemented. CE requires the use of indicators to evaluate the strides made both at the micro and macro levels. At the macro level indicators like GDP, job creation and carbon dioxide emissions are used to evaluate the progress. At the micro level the indicators used to measure CE are dependent on the CE strategy and measurement scope.

The Kokkola industrial park which is the largest cluster of inorganic companies in Northern Europe has had fifty years proven track record when it comes to CE with Boliden being a great example. The main symbiotic system around the park is the material and energy flow system which benefits the companies in the park and the Kokkola district. Boliden particularly has a circular economy policy which is applicable to all Boliden units around Europe be it its smelters or mines. Circular economy is an engagement for everybody as the adverse effects on the environment affect all. Like the term ‘circular’ implying the circle must be complete for the concept to be a success. Leadership is very important to push communities and the world to make better decisions regarding our environmental footprint. Wilma Mankiller quotes ‘In Iroquois society, leaders are encouraged to remember seven generations in the past and seven generations in the future when making decisions that affect people’ (the seventh-generation principle). (Haley, 2021)

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