Informing Sustainable Standards in

‘The Circular Economy’

Utilising technological and data solutions

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ABSTRACT

In our world of make, use and throw away we are now doing more damage to the planet than good, and this mindset has become unsustainable. One of the solutions to this problem is the 'Circular Economy' (CE). The CE replaces the concept of end-of-life production with restoration of natural systems, innovative design to design out waste and keeping products and materials in circulation for as long as possible.

This research will use data science and statistical information to provide a solid foundation (framework) for standards developers to frame the development of standards for the CE. The research will extend the current CE model by interjecting innovative ideas into areas of the CE process: data analysis, restriction of harmful chemicals removing them from the supply chain, research into Local Value Creation (LVC) and research into Sustainable Development in the CE. The research will investigate how Radio Frequency Identification (RFID) tagging of products and materials provide a realistic way to trace products and materials in a CE management system. It will also expand the knowledge on digitization in standards development by analyzing key data streams connected to the CE in order to inform the standards development community of the need to develop a standard on the CE.

This research will use a mixed methodology by combining quantitative methods (data analysis) and qualitative data (case studies). This will be detailed in Chapter 3 – Methodology. The data collected from the literature review will drive four main Sections and four research questions in Chapter 4.

This research will analyse through Case Studies and research papers the uptake of circular thinking in China and the Ellen MacArthur Foundation and use the outcomes positive or negative to show practical applications for this research.

The objective conclusion of this research is to provide a framework for a European or International standard in order to fill the gap as no such Standard currently exists European or Internationally that addresses the CE.

A Framework with inclusions from the research will form a usable output from the research. This research will inform or be of interest to the Standards development community, data scientists, Circular Economy practitioners and environmental regulators.

The aim of this research is to provide a framework standard using underlying data and statistical information needed to develop a new Standard on the Circular Economy.

Once a Standard is developed and published it can be used by any organisation or group of organisations, country or individual wishing to manage internally and collectively their activities in order to transition to the CE and the Sustainable Development goal of responsible consumption and production.

This research has produced a framework from which sustainable standards can be developed. The data acquired from using RFID tags imbedded in products allows manufacturers to control and analyse the materials in their products specific to hazardous chemicals. This data can also be used to track the product through the supply chain and onto its product life cycle. The data gathered in the product example in this thesis tracks the potential use of hazardous chemicals in the product, this is important information for end-of-life decisions to be made on the product. The data can then be used to develop requirements and testing regimes for circular economy standards.

Having identified some of the main areas of future activity in the CE, this research i.e., the circular economy, data science and standards development will continue to evoke research in the CE for the foreseeable future.

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I would like to thank my family for leaving me alone to get on with this project, although I deliberately left them puzzled about it. Through all the stress, fatigue and loneliness I thank God that I have managed to complete this project.

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ABBREVIATIONS

AI : Artificial Intelligence

BAMB: Buildings as Material Banks

BOM : Bill of Materials

BRIICS: Brazil, Russia, India, Indonesia, China, and South Africa

BSI : British Standards Institute

CE : Circular Economy

CEC : Circular Economy Centre

CEFSP: Circular Economy Finance Support Platform

CEN : European Committee for Standardisation

CENELEC: European Committee for Electrotechnical Standardisation

CEPZ : Circular Economy Pilot Zones

CFC : Chlorofluorocarbons

CLP : Classification Labelling and Packaging

CPA : Circular Plastics Alliance

CRM : Customer Relationship Management

CTIP : Circular Transformation of Industrial Parks

DAS : Direct Attached Storage

DEFRA: Department for Environment, Food and Rural Affairs

DRC : Democratic Republic of Congo

EAP : Environment Action Programme

EC : European Commission

ECCE : Exeter Centre for Circular Economy

ECHA : European Chemicals Agency

EDA : Exploratory Data Analysis

EEA : European Economic Area

EEE : Electrical and Electronic Equipment

EEP : Electrical and Electronic Product

EGD : European Green Deal

EIB : European Investment Bank

EIP : Eco-Industrial Park

ELV : End of Life Vehicles

EMF : Ellen MacArthur Foundation

EN : European Standards

ERP : Enterprise Resource Planning

ETSI : European Telecommunications Standards Institute

EU : European Union

EULA : End User License Agreement

EuP : Energy using Product

FAO : United Nations Food and Agriculture Organization

GDP : Gross Domestic Product

GDPR : General Data Protection Regulations

GHa : Global Hectares

ICT : Information and Communication Technologies

InnovFin: EU Finance for Innovators

IoT : Internet of Things

ISA : International Society of Automation

ISO : International Standards Organisation

KPI : Key Performance Indicators

(LCA)1: Life Cycle Analysis

LCA : Life Cycle Assessment

LVC : Local Value Creation

MaaS : Mobility as a Service

MBA : Master of Business Administration

MEP : Ministry of Environmental Protection

MFA : Material Flow Analysis

MPN : Manufacturers Part Number

MRP : Material Requirements Planning

MSc : Master of Science

NAS : Network Attached Storage

NLP : Natural Language Processing

OECD : Organisation for Economic Co-operation and Development

OJ : Official Journal

PAS : Publicly Available Specification

PBB : Polybrominated Biphenyls

PBDE : Polybrominated diphenyl Ethers

PoHS : Prohibition on Hazardous Substances

PRC : People's Republic of China

REACH: Registration Evaluation Authorisation and Restriction of Chemicals

RE : Regenerative Economy

RT : Recycling Technologies

RFID : Radio Frequency Identification

RML : Rosemount Measurement Limited

RoHS : Restriction of Hazardous Substances

SAN : Storage Area Network

SDG's : Sustainable Development Goals

SCIP : Substances of Concern In Products

SME : Small and Medium sized Enterprises

SVHC : Substances of Very High Concern

TR : Technical Report

TS : Technical Specification

UK : United Kingdom

UN : United Nations

UNESCO: United Nations Educational Scientific and Cultural Organization

USA : United States of America

WBCSD: World Business Council for Sustainable Development

WEEE : Waste Electrical and Electronic Equipment

WEF : World Economic Forum

WFD : Waste Framework Directive

WG : Working Group

CHAPTER 1

INTRODUCTION

1.1 Introduction

The current way of living is described as a linear economic existence where we as nations operate on a take, make and dispose of model and every product has an expected end of life. I suppose you could argue that this does not change in "The Circular Economy" but just gets extended. However, the benefits of this so-called extension make it vastly beneficial to do. The scarcity of natural resources combined with the global consumption of these resources have increased significantly and continues to increase. The increase in consumption has led to the increase in waste generation. The waste generated and disposed of now needs to be managed in order to avoid damaging the environment. In order to deal with this problem and its eventual outcome, we need to find a sustainable solution. It requires a sustainable solution because there are so many variables in this equation, it is not only about resource efficiency, global consumption, waste management, eco-system preservation but also includes the environment, the financial and social economies, political agendas, cultural change and ethical considerations. Making decisions on such a wide range of topics requires reliable data i.e., data that gives visibility of where the problems and potential solutions lie. Data science gives this visibility. Already there is this circular vision which has "systems thinking" at its core (EMF1, 2015). In order to transform the linear economy to a circular economy collaboration of countries and experts is needed. The CE has become a high-profile issue not only in Europe but also in developing countries and countries in a state of economic turmoil and so developing a data centric Standard is seen as essential for a sustainable society.

Linear Economy Model

Figure 1.1: Linear Economy Model (Mezyed, 2015)

In Figure 1.1, the raw materials are converted to products that are later disposed of without considerations to the environment. Raw materials are used to cater for our basic needs, produce food, build living accommodation and vital infrastructure, make clothes for us to wear and consumer products for us to use. When these consumables become of no use to us, they are disposed of as waste.

K. Boulding (Greyson, 2007) contrasts a linear economy as in Figure 1.1 (which acts as though the world receives a flow of fresh resources and can dispose of wastes) with a circular, cyclic economy. Boulding notes that the linear economy is characterized both by environmental impacts such as pollution and by social impacts such as exploitative and violent behaviours. In modern times a wide range of inter-related impacts are observed, such as extreme inequalities, population expansion, urban sprawl, disease pandemics, public and personnel debts, psychological stress and depression, overeating, overworking, unemployment, alcoholism, smoking and drug abuse, suicides, failing pension systems, rising taxes, over-regulation, materialism, alienation, distrust, refugees, erosion of civil liberties, military occupations and terrorism. According to Boulding, attention must be given not only to symptomatic immediate problems but also to a long run vision of the deep crisis which faces mankind (Greyson, 2007). Boulding's contrast above weighs heavily on the social impacts and whilst this is true, a CE might not minimise these problems. However, they will be reduced in a CE. We are removing so much of our raw materials that it has become dangerously low. Continuing down this path of a linear economy is unsustainable hence the need for the CE.

1.2 The Circular Economy

The Circular Economy as defined by the World Economic Forum (WEF) is an industrial system that is restorative or regenerative by intention and design (WEF, 2019). A Circular Economy replaces the end-of -life concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals and aims for the elimination of waste through the superior design of the materials, products, systems and business models.

The Ellen MacArthur Foundation defined the CE as an industrial system that supports a restorative concept through intelligent design of materials, products and systems and the business model. This concept encourages the business activity to practically optimise products, components and materials at highest utility and value always, distinguishing between technical and biological cycles (Ripanti, 2016).

1.3 Circular Economy Model

Pearce and Turner were the first British environmental economists to conceptualise the Circular Economy (Su et al., 2013). They analysed the co-existence of economic and natural systems and proposed closed loop material flows.

The CE is based on re-using, repairing, refurbishing and recycling our existing materials and products for as long as possible.

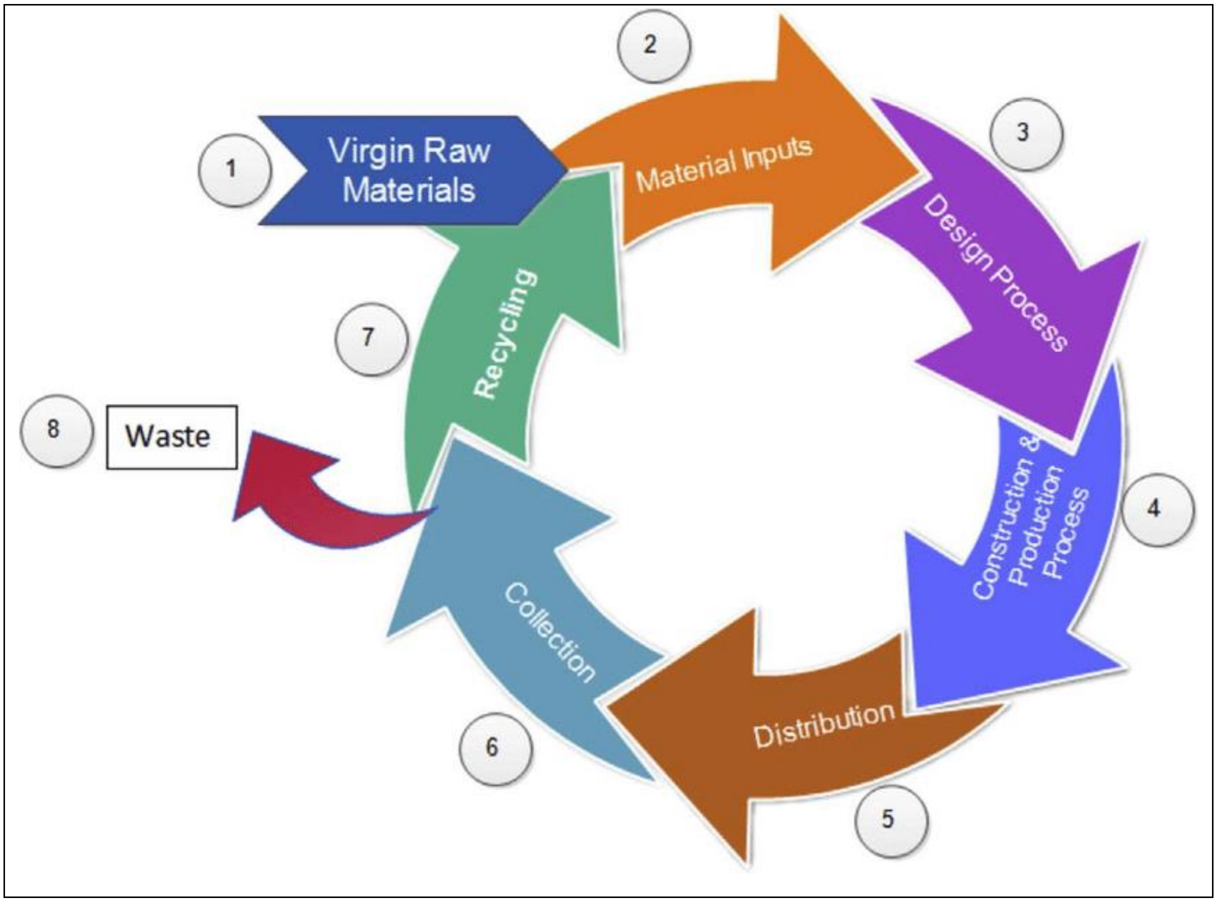

Figure 1.2: The Circular Economy Model (Akanbi, 2017)

Lord Rupert Redesdale, CEO at the Energy Managers Association gave at talk at the BSI Standards Forum 2015, the gist and conclusion of his talk was that the UK is using the current energy resources faster than they can be produced or stored. This dilemma is not sustainable and will eventually result in "black-outs" (a period during a massive power failure when the lack of electricity for illumination results in utter darkness except for emergency sources as candles) and "brown-outs" (a situation in which the voltage in a power grid is reduced below its normal level but not entirely eliminated).

The circular economy is intended to address some of these problems; it is ambitious but practical, eco-system friendly, restorative and impactful in a sustainable way. The CE represents a huge challenge in the light of depleting resources, a growing population, massive technological demand and unpredictable weather impacts.

Figure 1.2 Akanbi's CE model shows the phases represented in a CE model. The stages of design, production remanufacturing, distribution, consumption, use, re-use and repair, collection, recycling and back to the raw material constitute a good flow of areas that can be formulated. Each stage can be defined and a way of achieving each stage could be agreed by the stakeholders. Transitioning from a linear economy to a circular economy will contribute immensely to the proposal for 'circular economy' standards.

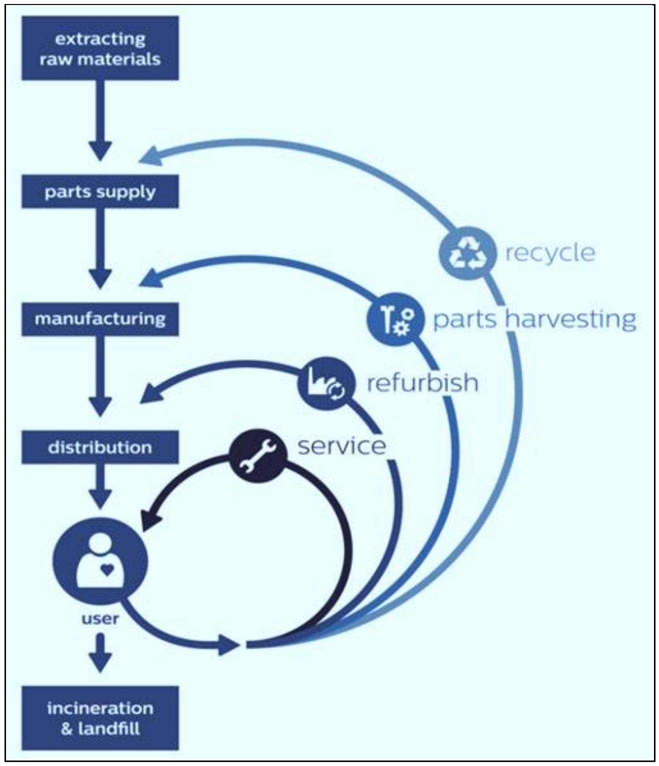

Figure 1.3: Four Concentric Loops

The CE can also be described as four concentric loops, see Figure 1.3. The inner circles describe high value activities and processes and moving towards the outer circles residual value is extracted until a product is recycled. The CE concept can be quite expansive as seen in Figure 1.3.

Research Aims and Objectives

The aim of this research is to provide the underlying data and statistical information needed to develop a new Standard on the Circular Economy.

The aim of this research is to create a framework for developing a standard for product circularity.

This research, will be able:

- To identify and discuss key factors contributing to a need for the Circular Economy
- To establish key theories underpinning the Circular Economy
- To analyze the impact of transitioning to a Circular Economy by examining the contributions of the Ellen MacArthur Foundation and China to the Circular Economy
- To propose a framework for Standards to be developed for the Circular Economy
- To recommend on the findings and key areas for future research on the Circular Economy

The main research findings will be divided into four Sections and answer the four research questions identified:

* Why is there a need for a Circular Economy Standard?

* What is the role of diversity in the Circular Economy?

* Is there any conflict between the Financial Economy and the Circular Economy?

* What will be the impact of applying a Circular Economy Standard to the environmental community?

This research will inform or be of interest to International Standards organisations (i.e. ISO, IEC, CEN/CENELEC, ASTM, ISEAL), National Standards organisations (Country specific), Standards writers, Standards commentators any organisation involved or interested in standardising the activities of the CE.

Readers of the results of this research will be able to use all or parts thereof to identify the need for a Standard on the Circular Economy, understand more about the Circular

Economy and some areas that are integral to the data analysed and look forward to some of the future activities regarding the circular economy.

Having identified some of the areas of future activity in the Circular Economy

This research will conclude in producing a Draft Framework Standard (DFS) for Circular Economy activities. This can then be used to produce a full International, European or National Standard or a New Work Item Proposal (NWIP) or a Publicly Available Specification (PAS). However, its goal is to ultimately be pivotal in using Data Science to inform a Standard for the Circular Economy that will serve the environmental future of the next generation as currently the gap is that there is no Standard at all.

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Figure 1.4: Thesis Structure

The thesis structure in Figure 1.4 provides an outline of the thesis.

Background

I currently work for Delta Mobrey Ltd as a Global Compliance Engineer.

My main role as a Global Compliance Engineer is to advise our company management, supervisors and engineers on all product and environmental issues and provide training as appropriate to secure technical and environmental compliance for new products and to maintain our large portfolio of existing product approvals worldwide.
In late 2014, I attended a presentation on Standards for Sustainability at British Standards Institute (BSI) Chiswick and on one of the slides titled - New/Expanding Areas of Interest was the topic Waste Prevention and the Circular Economy amongst other topics like, Environmental Product Foot-printing, Biodiversity Management, Climate Change Adaptation/Climate Resilience and Greenhouse Gas Management.
This was my minimalistic introduction to the Circular Economy and after the presentation I started to look deeper into this topic. Whilst there were/are organisations progressing the theory and practicalities of a Circular Economy there was No Standard on the Circular Economy and none that is data centric. Thus, the birth of what has become my research title "Informing Sustainable Standards in The Circular Economy, utilising technological and data solutions".

Relevance to Delta Mobrey Ltd and the Industry

Firstly, it is important to remind ourselves of the importance of standards to the World, Countries, Communities and Individuals. Standards are the distilled wisdom of people with expertise in their subject and who know the needs of the organizations they represent – people such as manufacturers, sellers, buyers, customers, trade associations and end users or regulators. Standards are knowledge, they are powerful tools that can help drive innovation and increase productivity. They can make organizations more recognizable, reputable and successful and contribute to making people's everyday lives easier, safer and healthier.

The suite of environmental standards we are currently working on follow on from ISO 14001- the principle Environmental Management System standard used by thousands of organizations all over the world including Delta Mobrey. ISO 14001 utilizes parts of other International and European standards and is therefore relevant to all organizations. ISO

14001 was written like ISO 9001 and will become the benchmark for organizations claiming environmental compliance. UK delegates held the Chair and Secretariat in the revision of ISO 14001:2015 and did a fantastic job, the UK is well respected around the world as a leading voice in Standardization.

Environmental Issues have been in the news and high on some country's agendas e.g. climate change, net zero, reduction of greenhouse gas emissions, carbon foot printing, reduction of waste and control of hazardous substances, plastics pollution. This suite of ISO 14000 standards we are working on is intended to standardize these activities, so they are more user friendly to the organizations that choose to use them. These standards are in high demand according to the International Standards Organisation (ISO).

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This Chapter represents an overall review of referenced journal papers and reports related to the thesis topic and incorporates a critical review of the key literature. With a view of guiding the subject matter for the Research questions and producing a draft framework standard that the researched information can be fed into. The underlying feature will be the collection and use of relevant Data to provide the wisdom for Standards development.

The European Commission created a legislative proposal on waste in December 2014, named - Towards a Circular Economy: A zero waste programme for Europe. Which they subsequently withdrew with a commitment to use its new horizontal working methods to present a new package by the end of 2015 to cover the full economic cycle rather than just waste reduction targets. The European Commission (EC) adopted this revised action plan in 2015 with the belief that it would accelerate Europe's transition towards a Circular Economy, boost global competitiveness, promote sustainable economic growth and generate new jobs.

For quite some time a profound preoccupation for some economists, politicians, environmentalists, sociologists or philosophers looking towards the coming decades consisted in searching for a new paradigm of development and growth that is feasible within the given limits of planet earth. There are already widely accepted concepts like "Sustainable Development" or "Low-Carbon Economy" that seem right but are just not good enough. In this paper, we analyse a broader approach that places human activity into a long-term historical perspective, namely the Circular Economy (Bonciu, 2014).

The EC's 2015 Action Plan identified five priority sectors to speed up the transition along their value chain, these are plastics, food waste, critical raw materials, construction and demolition, biomass and bio-based materials (Europa.eu, 2018).

The literature review is inspired by the background of the researcher, in environmental standards development, study of data science and the exploration of the reasonably new concept of the Circular Economy. The key words searched were – Circular Economy, Environmental Regulation, Sustainable development, Waste policy, Registration Evaluation Authorisation and Restriction of Chemicals (REACH), Waste Electrical and Electronic Equipment (WEEE), design, European, Re-use, Resource, Recycle, Efficiency and eco-design. The literature found has been integrated into the main text where relevant, organized into a series of related topics and summarized using the key issues.

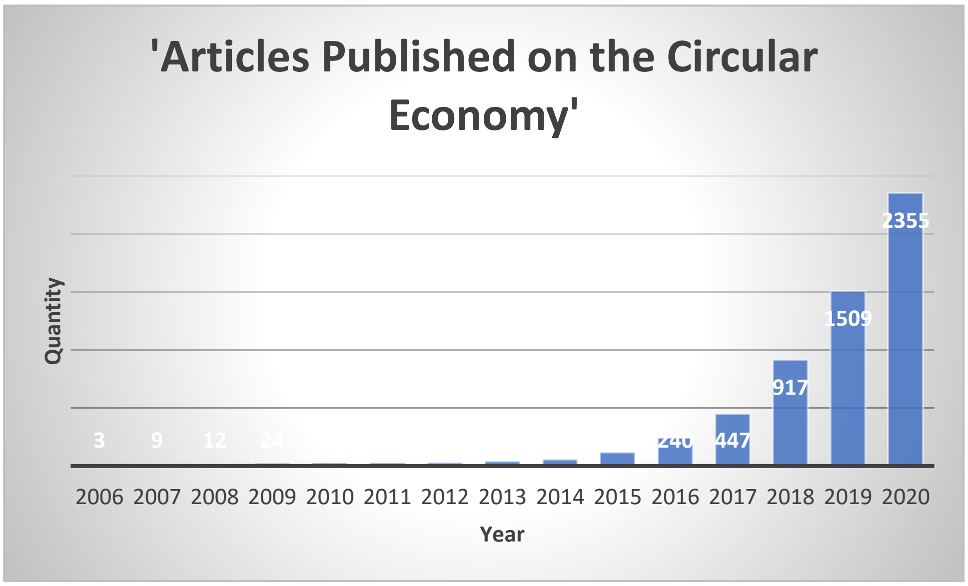


Figure 2.1: Articles Published on “The Circular Economy” (based on Alcalde-Calonge, et al, 2022)

Figure 2.1, Alcalde-Calonge, et al, 2022 analyses the current state of research on the CE using bibliometric tools that considered the main authors, institutions, countries and keywords of related academic studies. From the bar chart, the number of articles on the CE between 2006 and 2013 never went above fifty and then in 2014 the popularity of the CE started to rise sharply. It was around this time the author’s awareness was aroused and in 2015 the proposal from the European Commission to amend the European Waste Management Policy to include and promote the Circular Economy began to take shape. One of the searches conducted was done on Google Scholar, this search just for Circular Economy produced eighty-eight thousand six hundred results. The search was conducted in November 2020 and the results were filtered down to the time periods – since 2016, since

2019 and since 2020. The quantities are shown in chart below in Figure 2.2. A further Google Scholar search of "Circular Economy and standards" produced just two results, signifying there is a lack of research in this area.

No of Search Results from "Circular Economy"	
Date	Results
Since 2016	45,300
Since 2019	25,400
Since 2020	15,000

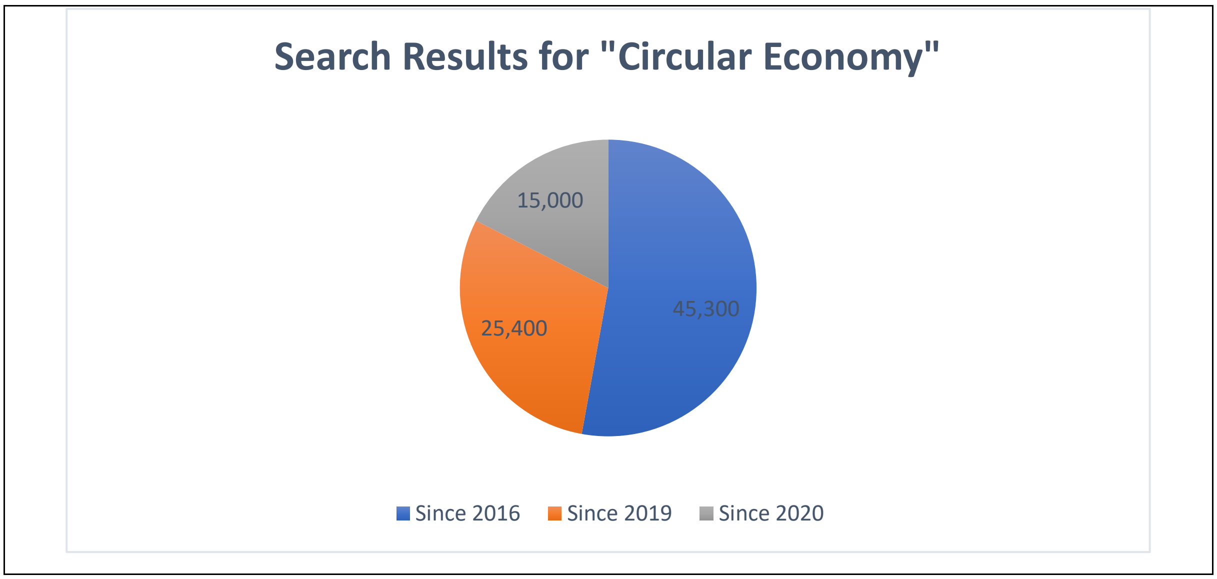


Figure 2.2: Google Scholar Circular Economy Search Results

Transition Towards a Circular Economy

There is a need for metrics to analyse complex business models in the circular economy. Since new sustainable business models are part of the transition towards a circular economy, there is a need for a combined analysis of value and eco-burden. A circular transition framework would reveal both pitfalls and opportunities when implemented. It is important to know where the main stages lie or take place so changes can be made in bitesize chunks in order to transition to a CE. The quest for a sustainable society is the quest for solutions in a Circular Economy. The notion that materials in the techno sphere must be recycled, toxic emissions must be eradicated, fossil-based energy must be replaced by renewable energy and that materials from the biosphere provide new opportunities for innovations, is not new. New, is however, the focus on the transition from the old, linear and unsustainable systems towards new circular systems. Essential for such a transition is that new business models must be developed to support this transition. These business models must have extra added value (in comparison to the market competition) combined with lower eco-burden, less resource depletion as well as less environmental pollution (Scheepens, 2015). Scheepens presents the transitioning from the old (for some current) linear and unsustainable model to the new circular economy model. These newer models must have added value built in to achieve the sustainable development goals being brandished. Scheepens applies the LCA-based Eco-costs Value Ratio model to analyse the potential negative environmental effects on businesses introducing the CE model. The circular transition framework reveals pitfalls and opportunities in implementation, like the coordination between business models and aligned governmental policies. Having a system of showing added value to the Circular Economy can only be positive for the development of standards on the Circular Economy. The European Commission created a European Circular Economy Stakeholder Platform as a virtual open space aimed at promoting Europe's transition to a circular economy by facilitating policy dialogue among stakeholders and by disseminating activities, information and good practices on the Circular Economy (Europa.eu, 2017).

Circular Economy systems keep the added value in products for as long as possible and eliminate waste. They keep resources within the economy when a product has reached the end of its life, so that they can be productively used again and again and thus create further value. Transition towards a more Circular Economy requires changes throughout the value chains, from product design to new business and market models, from new ways of turning waste into a resource to new models of consumer behaviour. This implies full systemic change and innovation not only in technologies, but also in organisation, society, finance methods and policies (Europa.eu, 2017).

A Circular Economy is an approach that would transform the function of resources in the economy. Waste from factories would become a valuable input to another process-and products could be repaired, reused or upgraded instead of thrown away. Resource consumption targets that reflect environmental constraints should be considered at a global level. Coordination of national policies would help create a level playing field across major markets (Preston, 2012). The circular economy is seen here as a model for industrial organisations that will help developing countries to industrialise and develop their countries to increase wellbeing and reduce vulnerability to resource price shocks but without placing unsustainable pressure on natural resources and negatively impacting the environment. Hence, Preston (2012) explores the concepts of the Circular Economy, its key components, challenges and opportunities and the importance of international cooperation.

Critical Raw Materials

Raw materials are essential to our everyday lives. Millions of jobs rely on the availability of raw materials. The EU's raw materials policies aim to help raise industry's contribution to EU GDP to around 20% by 2020.

In a world where humans occupied just a small part of the global eco-system the concept of unlimited production seemed possible mainly because the facts were not available (it was theoretical). A few decades later and this proportionate figure has dramatically increased, and we reached a point in 2010 (according to Global Footprint, Annual Report 2012) when the overall needs exceeded more than 50% of the regenerative capacity of the earth. This means that the continuation of current levels of extracted resources from the environment, the increase in production and failure to reduce our waste is making it impossible to achieve sustainability. The research in this report "The European Economy: from a linear to a Circular Economy "based on 2011 data, shows that if all the people on Earth would live as a developed country citizen, then we would require 4.1 Earths. This is perfect reason for a standard(s) on the Circular Economy.

The diagram Figure 2.3 (below) from the EU's website shows the initiatives the EU are focusing on- namely the Raw Materials Initiative, Horizon 2020 and the European Innovation Partnership. The focus here in line with this thesis is on non-food and non-fuel raw materials, both primary sourced (from mining and forestry) and secondarily sourced (from e.g. recycling). More detail and data analysis will be done in future chapters on this topic.

Figure 2.3: EU Initiative Focus (source - europa.eu, 2017)

The EU Commission has identified twenty critical raw materials listed because of their risks of supply shortage and their impacts on the economy are higher than the other raw materials. The chart indicates clearly that China is the most influential in terms of global supply of the twenty critical raw materials. The risks associated with concentrated areas of production are in many cases compounded by low substitutability and low recycling rates. A list of these twenty critical raw materials can be found in the Appendix. The critical raw materials list was updated in 2015 and now includes forty-one materials or material groups that are at risk, but we need to maintain our economy and lifestyle. A list of these forty-one critical raw materials can be found in the paper (BGS Risk List, 2015).

Waste Management

In the past the creation of waste in connection with production and consumption was accepted as a necessary evil. Today, that apparent common sense is increasingly being challenged: circular economy, zero waste, closed-cycle, resource efficiency, waste avoidance, re-use, recycling – all these terms can be attributed to the ideal of achieving a world largely without waste, and instead one with a responsible attitude to resources, materials, products and the environment. Waste management plays a central role in the Circular economy: it determines how the European Union waste hierarchy is put into practice. The waste hierarchy establishes a priority order from prevention, preparation for reuse, recycling and energy recovery through to disposal, such as landfilling. The way we collect and manage our waste can lead either to high rates of recycling and to valuable materials finding their way back into the economy, or to an inefficient system where most recyclable waste ends up in land fill or is incinerated, with potentially harmful environmental impacts and significant economic losses. To achieve high levels of material recovery, it is essential to send long-term signals to public authorities, businesses and investors and to establish the right conditions at European Union level including consistent enforcement of existing obligations (European Commission, 2015).

In the last decades, green and sustainable supply chain management practices have been developed, trying to integrate environmental concerns into organisations by reducing unintended negative consequences on the environment of production and consumption processes. In parallel to this, the circular economy discourse has been propagated in the industrial ecology literature and practice. Circular economy pushes the frontiers of environmental sustainability by emphasising the idea of transforming products in such a way that there are workable relationships between ecological systems and economic growth. Therefore, circular economy is not just concerned with the reduction of the use of the environment as a sink for residuals but rather with the creation of self-sustaining production systems in which materials are used repeatedly. Through two case studies from different process industries chemical and food, this paper compares the performances of traditional and circular production systems across a range of indicators. Direct, indirect and total lifecycle emissions, waste recovered, virgin resources use, as well as carbon maps which provide a holistic visibility of the entire supply chain are presented. The paper asserts that an integration of circular economy principles within sustainable supply chain management can provide clear advantages from an environmental point view. Emerging supply chain management challenges and market dynamics are also highlighted and discussed (Genovese et al, 2015). The main objective of Genovese's paper has been to enhance the credentials of sustainable supply chain management practices by aligning them to circular economy strategies.

Whilst it is true that all waste streams should be included regardless of whether they are from households, businesses, industry, mining or the construction industry, this research does not include food waste.

The recycling rates and use of recycled materials in the European Union are steadily increasing. Overall, according to Eurostat (2019) the EU recycled approximately 55% of all waste excluding major mineral waste in 2016 (compared with 53% in 2010). The more important recycled waste streams for this report are overall packaging waste at 67% in 2016 (compared with 64% in 2010) and plastic packaging waste at 42% in 2016 (compared with 24% in 2010). The waste of WEEE, such as computers, televisions, fridges and mobile phones, which include valuable materials which can be recovered (e-waste) in the EU reached 41% in 2016 (compared with 28% in 2010), (Europa.eu, 2019). Prevention objectives are significantly reinforced requiring Member States to take specific measures to tackle food waste and marine litter as a contribution to achieve EU commitments to the UN SDGs (Europa.eu, 2019).

If global problems and such as climate change and waste remain unsolved, society can choose whether to continue attempting to incrementally reduce wastes and lessen impacts or consider a more ambitious approach that may be easier to implement. Greyson's paper suggests how an approach designed to prevent waste and other global impacts could be based upon the established practices of recycling, circular economic policy and recycling insurance (Greyson, 2007). This paper proposes to prevent rather than reduce the accumulation of waste. Resource scarcity is replaced by resource abundance, with benefits for technological, economic, environmental and social progress. Greyson argues that for many who are committing to 'Zero waste' only ever achieve reduced waste. This is more in line with the concepts of a circular economy and therefore it would be more realistic to have a standard that controls what happens to the waste.

Kissling (2013) aims to identify specific and generic success factors and barriers in the re-use of electrical and electronic equipment for a variety of different operating models. The scope of the study is ICT and large household appliances. Success factors and barriers for re-use were identified through the conducting of semi-structured interviews with 28 case study partners representing the different models (Kissling, 2013). This is very useful for knowing what works and what fails when you are developing/designing a system or standard, it saves valuable resources.

Mobile phones are the most ubiquitous electronic product on the globe. They have a relatively short life cycle and because of their perceived in-built obsolescence, discarded mobile phones represent a significant and growing problem with respect to WEEE. An emerging and increasingly important issue for industry is the shortage of key metals, especially the types of metals found in mobile phones. Hence, the main aim of Ongondo's study on mobile phone collection re-use and recycling in the UK was to assess and evaluate the voluntary mobile phone take back network in the UK (Ongondo et al, 2013). This report was to be used to source data for analysis on mobile phone recycling in the UK. The study is probably the first snapshot into the networks that organise the take back of mobile phones and this information will contribute to show areas and schemes involved in recycling. As the world population, consumption and economy grow, a complex and multi-dimensional approach is needed to manage a rising tide of solid waste. Morgan presents a realistic view of solid waste management and basically concludes that it is not as easy as you think (Morgan, 2015).

Standards

A Standard is a document that provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for purpose. Thousands of Standards are published every year by National, European and International Standards organisations, but they are written by a committee of experts from a range of relevant stakeholder groups. Stakeholder groups could come from individual subject experts, industry, government, academics, charities or consumer groups. Standards are developed by consensus meaning that everyone in the working group must agree on the content being developed. Standards are voluntary, although some are used to underpin legislation and are generally seen as best practice.

Standards support market-based competition and help ensure the interoperability of complementary products and services. They reduce costs, improve safety and enhance competition. Due to their role in protecting health, safety, security and the environment, standards are important to the public (BSI, 2017).

The survey conducted by the ARC Advisory Group shows a positive trend towards the importance of standards in the future, with a high percentage of respondents indicating that usage of relevant standards will become more mainstream than not and that the rise in the innovative technologies will accelerate the development and usage of standards. The answers to the survey were more qualitative than quantitative and not as substantive as it should have been. Leveraging the growing volumes of data such as satellite imagery, continuous sensor data from industrial processes, social media data, and data from environmental sensors requires different statistical machine learning techniques (Balaprakash, 2021). Some key findings from the survey are recorded in Chapter 4, however some comments from respondents are worth noting. Standards are the optimum method of networking, learning from subject matter experts and sharing your knowledge with others (Wilkins, 2020).

Continuing with the data science theme, the book authored by Shah, (2021) added more definition to the methodology chapter, with precise definitions of some key elements in a typical data science process. The book has a good blend of simple clear definitions and practical examples, there is a good flow to the book from section to section and chapter to chapter. Shah, (2021) introduces good suggestions on how to and where data science fits into our normal daily lives, which is welcome to know. On the negative side the letter fonts can be at times difficult to read and changing between fonts. Santschi, et al (2022) researched a data powered circular economy to provide some positive outcomes using unstructured data. They also provided good examples from their research, for example when investigating litter prevention measures, non-traditional data analysis can help with the identification of communities that employ particularly effective practices. The behaviour of these ‘positively deviant communities’ can then be studied in more detail to eventually replicate their resilience-building practices in other regions Santschi, et al (2022). This practice could be modelled and adapted to fit other similar schemes, for example, areas where there is waste land, this waste land could be turned into useful land for growing crops or planting trees.

Increasing Interest in the Circular Economy

There is no doubt that interest in the Circular Economy throughout Europe and across the world is growing year on year. This is partly because we are not acting fast enough to transition to a Circular Economy. The Circular Economy is gaining increasing attention in Europe and around the world as a potential way for our society to increase prosperity, while reducing dependence on primary materials and energy.

The growing importance of the concept of the Circular Economy to attain sustainable development has encouraged scholars to propose different ways to understand it. According to Prieto-Sandoval et al (2017) studies carried out on a systematic literature review resulted in four main outputs: a knowledge map of the Circular Economy, an analysis of the main notions of the concept, principles and determinants of a Circular Economy.

In the last few years, the Circular Economy has been receiving increasing attention worldwide 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 Circular Economy 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 (Ghisellini et al, 2015). Ghisellini promotes the adoption of closing-the-loop production patterns within an economic system, the Circular Economy 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 increased attention in the Circular Economy concept is due, in part, to its capacity to provide the basis for reconciling the problem of how to promote productivity while considering the externalities of the production process, the consumption of the products and the end-of-life impacts (Sauve et al, 2015).

Reaction in Europe

The European Commission put forward to Europe a proposal for the Circular Economy in December 2014 – Towards a Circular Economy (European Commission, 2014). But in March 2015 the Commission withdrew this proposal amid growing concerns and disapproval from Member states and interested parties to make way for a more ambitious proposal to be more inclusive of the whole Circular Economy. In December 2015, the European Commission presented their new action plan for the Circular Economy.

What is the role of Diversity in the Circular Economy?

Whilst diversity can mean different things to different individuals, in the context of this thesis, diversity is the ability of the Circular Economy to be diverse or different allowing for inclusivity, as long as the concepts/examples are within the boundaries of the Circular Economy.

Despite their different assumptions and strategic intentions, the concepts of the Circular Economy, the Green Economy and the Bio Economy are joined by a common ideal, to reconcile economic, environmental and social goals. These three concepts are currently mainstreamed in academia and policy making as key sustainability avenues (D'Amato et al, 2017).

This research does not delve too deep into the concepts of the Green and Bio economies but highlights some areas of commonality with the Circular Economy in order to show how the diversity of the Circular Economy adds to the circularity needed to include the concepts that are the framework of the Circular Economy. Diversity is needed to accommodate the breadth needed to develop a Standard that will affect many consumers. D'Amato's research identifies that the underlying idea in creating diversity in the Circular Economy is the transformation of relevant industries by – product into a resource for a second industry with a strong emphasis on inter-sectorial dynamics and cooperation. As the individual concepts (Circular Economy, Green Economy and Bio Economy) gain popularity, they become influential to various societal actors (academics, practitioners, charities, NGO's, and businesses) to support their own interests and activities. Each actor interprets and applies these concepts in different ways, yet knowingly or unknowingly they are conferring a degree of internal diversity.

The Circular Economy as an Ecology

Ecology addresses the full scale of life, from tiny bacteria to processes that span the entire planet.

Systems thinking focuses on non-linear systems in which feedback loops play a fundamental role. In these systems, the combination of uncertain environmental factors and feedback give an unpredictable outcome. But thinking about these relationships and materials flows is crucial for understanding how the system can be optimised. This requires a long-term focus. At various levels of scale, systems influence each other, and relationships of dependency and feedback loops exist that contribute to the resilience of the Circular Economy (Stegeman, 2015). Systems thinking, and the Circular Economy will be further developed (Stahel, 2016).

Ongondo's (2013) studies on ICT reuse in socio-economic enterprises was designed to determine the impacts of the repair, refurbishment, and reuse of ICT products. The study highlighted that the long-term economic viability of these organisations may be uncertain; promotion and advertising of their services, widening sources of reuse products, adoption of standard quality certification and better access to potentially reusable equipment can help improve their economic standing. The study also highlighted the potential to contribute to a closed-loop economy data from this study will be analysed in Chapter 4.

The Ecological Footprint tracks the use of six productive surface areas: grazing land, agricultural land, fishing grounds, built-up land, forest land and carbo capture land (footprintnetwork, 2012). This is referenced in Figure 4.30. The ecological footprint was conceived by Mathis Wackernagel and William Rees at the University of Columbia. It launched the broader Footprint movement, including the carbon footprint (footprintnetwork, 2012). The ecological footprint and the carbon footprint are now regularly used by organisations, scientists, governments, environmentalists, institutions and individuals to monitor and forecast environmental resources to advance sustainable development. There is a lot of quantitative data required to accurately report these footprints and this report provides some of the calculations.

The Circular Economy and Reverse Logistics

Reverse Logistics – is the handling of the return flows of a product or equipment back from consumer for reuse, recovery, or recycling.

Ripanti et al, (2016) research paper aims to demonstrate the links between the Circular Economy and Reverse Logistics with a specific goal to identify the Circular Economy principles that could be relevant to the design of reverse logistics systems/operations, especially in the case of product remanufacturing. Ripanti et al, (2016) has adopted the desk-based research approach, where data are mined from relevant publication databases and other scientific resources, using a wide range of keywords and phrases associated with the Circular Economy and reverse logistics. These are combined with publicly available materials and various media case studies, videos, seminars and presentations related to the Circular Economy, reverse logistics and remanufacturing. The fact is that the Circular Economy principles are essential and relevant to reverse logistics. The Circular Economy principles can be found in Chapter 4. Ripanti et al, (2016) aims to develop a new framework to design Reverse Logistics operations based on Circular Economy values that can increase the effectiveness and efficiency of Reverse Logistics operations.

The Circular Economy is outlined in Prieto-Sandoval's research paper as a cycle of the extraction and transformation of resources and the distribution, use and recovery of goods and materials. Natural resources from the environment are transformed into products or services for use by consumers (Prieto-Sandoval, et al, 2017). The transition to a circular economy highlighted by Prieto-Sandoval requires eco-innovations to close the loop of the products lifecycle, get valuable products to others from waste and solve the needs of environmental resilience despite the tendency towards economic growth (Prieto-Sandoval, et al, 2017). Prieto-Sandoval's research also highlights the evolution of eco-innovation as a sociological change to an eco-centric vision of nature, which is influencing the way society is evolving in this environmental landscape.

The diversity of the Circular Economy can be seen in the characterization at three different levels: Micro, Meso and Macro (Ghisellini, et al, 2015).

At the Micro level: this represents where companies and consumers reside. Companies are focussed on their own improvement processes and eco-innovation development.

At the Meso level: this represents all inter-industries and inter-firm networks. Here reside companies who belong to an industrial symbiosis that will benefit not only the regional economy but also the natural environment.

At the Macro level: this represents the highest level where cities, countries and international agencies reside. The focus is on the development of eco-cities, eco-municipalities or eco-provinces through the development of environmental policies and institutional finance.

The European Commission has been deeply involved in financing the transition of Europe to a circular economy, recognizing that without dedicated finance this transition will not happen.

The financial crisis, from which Europe appears to be slowly and partially emerging, did not reduce the focus of European citizens on environmental issues. In fact, using resources more efficiently for cost, as well as environmental reasons has only become more important as a result. (European Commission, 2014)

European industry already recognises the strong business case for the improvement of resource efficiency. The report from the European Commission estimates that resource efficiency improvements all along the value chains could reduce material inputs needs by 17 – 24% by 2030 and a better use of resources could represent an overall saving of 630 billion euros per year for European industry (European Commission, 2014).

The National Consumer Federation's (NCF) researched report in response to questions being asked by the Competition and Markets Authority (CMA) on consumer priorities for 2015/16 has produced a chart (shown in Figure 4.1) showing the UK regulatory burden on business. The key figure for the purposes of this report is that of: Recycling and Environmental regulations is 26% of the total regulatory burden on UK businesses. Calculating this into a monetary value using the £10.75 billion figure reported as the total regulatory burden. Then Recycling and Environmental regulatory burden is £2.795 billion, a huge amount based on 2008 figures, (cebr, 2015).

Is there a future for e-waste recycling? Yes, and it is worth billions. This research report presents the recycling of Waste Electrical and Electronic Equipment (WEEE) as an economic assessment of present and future e-waste streams. Around the world, 30 to 50 million tons of electronic devices are tossed away every year. That volume of e-waste is expected to increase by an impressive three to five percent per year as consumers demand more and more "smart" products. Koh and her colleagues estimate potential revenues from recycled e-waste at more than two billion Euros in the year 2014 for the European market alone. The value associated with those recycled resources is expected to rise by the year 2020 to more than 3.5 billion Euros (Morgan, 2015).

Morgan, (2015) presents crucial evidence to inform the population and encourage them to think about the amount of embedded value and precious materials contained in the electronic products that are consumed daily. The paper identifies one of the biggest challenges in dealing with e-waste is product design. Products are increasingly smaller, more compact even on a nanoscale, this makes it much more difficult to recover precious, rare-earth materials. A circular economy standard will address design issues in conjunction with the Eco-design regulation.

The Circular Economy

The Circular Economy economics like environmental economics is concerned with identifying and solving problems related to damage and pollution associated with the flow of residuals. In this context, the principles underlying the Circular Economy suggest that, by assuming the planet as a closed system, the number of resources depleted in a period is equal to the amount of waste generated in the same period. The principles of the Circular Economy thus reveal an idealistic ambition of pushing the boundaries of sustainable supply chain management practices. Such practices are ultimately concerned with the reduction or the delay of unintended negative impacts on the environment due to cradle to grave linear material flows (Genovese, et al, 2015).

In Europe, socio-economic enterprises such as charities, voluntary organisations and not-for -profit companies are involved in the repair, refurbishment and reuse of various products. ICT Re-use in Socio-economic enterprises (Ongondo, et al, 2013), characterises and analyses the operations of socio-economic enterprises that are involved in the reuse of information and communications technology. Using findings from a survey, Ongondo specifically analyses the reuse activities of socio-economic enterprises in the UK from which Europe-wide conclusions are drawn.

Demand for various scarce raw materials for the manufacture of electronic products has forced countries to rethink their strategies for managing WEEE. The findings of this report provide a detailed insight into the reuse operations of socio-economic enterprises and present and analyse previously unobtainable data.

The main purpose of George, (2015) is to present a theoretical model incorporating the concept of circular economic activities. Constructing a circular economy model with two types of economic resources, namely a polluting input and a recyclable input. Overall, the results indicate that the factors affecting economic growth include the marginal product of the recyclable input, the recycling ratio, the cost of using the environmentally polluting input and the level of pollution arising from the employment of the polluting input (George, 2015).

Digitalisation can be seen as one of the enablers of the Circular Economy due to its building visibility and intelligence into products and assets such as knowledge of the location, condition and availability of assets. One of the key points in CE-based business models is that instead of selling products, durable products are leased, rented or shared wherever possible. Thus, the shift towards product service systems (PSS) is suggested as being one of the key solutions in accelerating the transformation towards the Circular Economy and digitalisation is a major enabler in this process (Antikainen, et.al, 2018).

Resilience to Climate Change

The Paris Agreement builds upon the Convention and brings all nations to a common cause to undertake ambitious efforts to combat climate change and adapt to its effects, with enhanced support to assist developing countries to do so too. The central aim of the Paris Agreement is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius. Additionally, the agreement aims to strengthen the ability of countries to deal with the impacts of climate change (The Paris Agreement, 2019).

Most climate scientists agree the main cause of the current global warming trend is human expansion of the "greenhouse effect" — warming that results when the atmosphere traps heat radiating from Earth toward space Gases that contribute to the greenhouse effect are water vapour ($H20$) methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2). (nasa.gov)

The United Kingdom is one of the leading nations developing standards on climate change and in particular “Adaptation to Climate Change” – ISO 14090 and “Adaptation to Climate Change” – Vulnerability, impacts and risk assessment – ISO 14091.

Life Cycle Assessment (LCA) is a fundamental tool used in Eco-design. However, it can be costly and resource intensive. We take steps towards the automation of the inventory and impact analysis stages of LCA via the proposal and development of Case-Based Reasoning (CBR) procedure to estimate the ecological effects of a product (Jeong, et al, 2015). Jeong, (2015) presents LCA as a key component in many eco-design methodologies and its use is justified in obtaining ecological certification or satisfying regulations that limit the ecological effects of products. The proposed research will use LCA in its reuse and recycling phase.

Design has a great role to play in sustainability. Some issues of sustainability and their impact on design remains poorly studied. Specifically, when it comes to the issue of local value creation, the literature in design is still limited. However, the Local Value Creation (LVC) thinking can be a great insight for designers to develop more eco-innovative concepts, through new product design, new services and new business models (Tyl, et al, 2015).

Local value creation in eco-design will expand the current thinking of the Circular Economy. This area will require a lot of thought, but I believe it is conducive to the sustainability concepts of the circular economy. This approach can be used in this research to expand the current model of the Circular Economy.

Future thinking - Horizon 2020 – Research, Innovation

Horizon 2020 is the biggest EU Research and Innovation programme ever with nearly 80 billion euros of funding available over seven years from 2014 to 2020, in addition to the private investment that this money will attract. It promises more breakthroughs, discoveries and world firsts by taking great ideas from the lab to the marketplace (echa.europa.eu – Horizon 2020).

The Circular Economy represents a development strategy that entails economic growth without increasing consumption of resources, deeply transforming production chains and consumption habits and redesigning industrial systems at the system level. It relies on innovation being technological, social and organisational. It requires a new portfolio of skills and knowledge as well as new financial instruments and multi-stakeholder involvement.

From the total EU financial contribution allocated through Horizon 2020 - 65% is sustainability related, with 15.7 billion euros and 28% is climate related representing 6.6 billion euros (European Commission, 2018).

Schroeder (2018) provides an overview on the relationship between the Circular Economy practices and Sustainable Development Goals targets, additional research is required to further explore and analyse in depth the synergies and opportunities between Circular Economy practices and Sustainable Development Goals targets in specific country contexts (Schroeder, et al, 2018).

Innovative digital technologies have enabled the formation of multiple Product Service-Systems (PSS) with considerable economic, environmental and societal benefits. One of the most promising paradigms, which is inspired by business models and value propositions is the concept of the Circular Economy (Pagoropoulos, et.al, 2017).

The Circular Economy would mean a radical shift in how materials are used throughout the economy. With the right incentives, innovation will deliver more sustainable materials – plastics, for example, would increasingly be derived from plants rather than fossil fuels. Nanotechnology and biotechnology have the potential to deliver materials with increased strength, reduced weight and other useful properties. At the end of the product's life these materials would biodegrade or could be easily separated so that they could be reused (Preston, 2012).

Sustainable Development Goals

Sustainable development requires balanced and simultaneous consideration of the economic, environmental, technological and social aspects of an investigated economy, sector or individual industrial process as well as of the interaction among all these aspects. The Circular Economy has the potential to understand and implement radically new patterns and help society reach increased sustainability and wellbeing at low or no material, energy and environmental costs (Ghilsellini, et.al, 2015).

Schroeder, (2018) suggested that Circular Economy practices and related business models can help to achieve several of the sustainable development goal targets. The strongest relationships exist between Circular Economy practices and targets of SDG 6 (Clean Water and Sanitation), SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Work and Economic Growth), SDG 12 (Responsible Consumption and Production) and SDG 15 (Life on Land), (Schroeder, et al, 2018).

Although there are twelve sustainable development goals as illustrated in Chapter 4.5 of this thesis. The focus for the Circular Economy is Goal number twelve Responsible Consumption.

The intermeshing of disciplines from the natural sciences, social sciences, engineering and management has become essential to addressing today's environmental challenges. Sauve et al, (2015) explores three alternative environmental concepts used in transdisciplinary research, and outlines some of the epistemological and practical problems that each one poses. It pays particular attention to the increasingly popular concept of the circular economy and contrasts it with the more commonly used concepts of environmental sciences and sustainable development. Sauve et al, (2015) introduces the alternative concepts of trans-disciplinary research that impact or influence the circular economy. This is massively important in getting the broad picture on the Circular Economy.

Circular Economy Measures

The rise in conversation on the Circular Economy has reached the point where we need to be measuring the impacts of a transition to it and the progress being made and possible future outcomes. Measuring progress towards a Circular Economy will involve much more detailed mapping of how resources move within the economy than there is now. Just as important are the economic impacts of the Circular Economy along value chains at company and sector level. Information technology initiatives is continuing to enhance the ability to track both resources and value flows, enabling companies to benefit from identifying wasteful processes along the supply chain and model new approaches.

Measuring progress in the Circular Economy is challenging and what and how adopters of Circular Economy practices decide to measure will depend on their own objectives, scopes and audiences. Research conducted by the WBCSD found that 74% of their interviewees indicated that their company use their own framework for measuring circularity. Therefore, the cacophony of circular metrics popping up across sectors and geographies has created an environment of competing and often conflicting indications of actual circularity progress achieved (WBCSD, 2018).

Since the 1990's Product Service Systems (PSS) have been heralded as one of the most effective instruments for moving society toward a resource-efficient circular economy and creating a much-needed resource revolution. Tukker, (2015) reviews the literature on PSS over the last decade and compares the findings with those from an earlier review. Tukker (2015) defines product service systems as a marketable set of products designed to meet the customer's needs. However, this extends to identify resource efficiencies and circular economic concepts. Consideration is given to a large amount of reference papers on PSS. In the conclusion of this study there was no definite findings that PSS was more resource efficient but there were factors that would promote a circular economy and identifiable tools to support a Circular Economy framework.

Product life spans of electric and electronic products are in decline, with detrimental environmental consequences. This research maps the environmental impacts of refrigerators and laptops against their increasing energy efficiency over time and finds that product life extension is the preferred strategy in both cases. Bakker et al, (2014) explores a range of product life extension strategies and concludes that tailored approaches are needed. Product lifespans in our developed countries have steadily declined over the past decade, leading to an increased throughput of materials and therefore more waste. The negative environmental impacts of the increase in material use means the depletion of environmental resources is becoming critical. A new Circular Economy standard would address these problems. Bakker case studies the refrigerator and laptop as candidates for life-cycle assessment and presents its findings. Quantities of collected mobile phones in the UK can be analysed as part of a recycling program that contributes to circular economy activities.

There are five main reasons why business is interested in measuring their circularity:

To drive business performance strategy

To justify achievements externally

To integrate circularity across the business

To manage risk associated with the existing linear business model

To know the impact of their circular activities

(WBCSD, 2018)

The Ellen MacArthur Foundation

The foundation was launched in 2010 to accelerate the transition to the Circular Economy. Since its creation, the charity has emerged as a global thought leader, establishing the Circular Economy on the agenda of decision makers across business, government and academia (EMF1, 2015).

The EM Foundation defines the Circular Economy as: A framework for an economy that is restorative and regenerative by design.

The EM Foundation's work focuses on six interlinking areas:

- Learning – developing the vision, skills and mindsets needed to transition to a Circular Economy
- Business – catalysing circular innovation and creating the conditions for it to reach scale.
- Institutions, Governments and Cities - catalysing circular innovation and creating the conditions for it to reach scale.
- Insight and Analysis – providing robust evidence about the benefits and implications of the transition.
- Systemic Initiatives – transforming key materials flows to scale the Circular Economy globally.
- Communications – engaging a global audience around the Circular Economy (EMF1, 2015).

The sources from the EMF have provided thought-leading insights and analysis to the thesis and have defined a scope beyond the constraints being applied but insightful, nonetheless.

The Circular Economy in China

For more than fifteen years, China's government has been a frontrunner on Circular Economy policies, with a focus on addressing pollution, promoting resource efficiency and industrial ecology. Building on these efforts, in 2017 the Chinese government introduced a new set of policies, centred on concepts such as product redesign, and the sharing economy, which highlight the innovation and value creation opportunities of a Circular Economy approach – particularly for Chinese cities.

Circular Economy opportunities in China's cities have been identified in five focus areas, these are:

Built Environment

Mobility

Nutrition

Textiles

Electronics (EMF5, 2018)

The Circular Economy in China is a direct outcome of the national political strategy top-down approach, and its implementation is structured following both a horizontal and a vertical approach. Chinese national governmental policy aims to transform not only the industry but also the socio-economic organisation of the society at all levels. The top-down approach of the Chinese national strategy is also reflected on the instruments used, that are mainly of command and control rather than market based (Ghilsellini et.al, 2015).

With rapid economic growth, the energy consumption rate has greatly increased in China. Soon, China will be faced with the formidable challenge of energy shortages. Conservation of energy will be crucial for China's process industries. Based on the conditions in China, the government instituted the basic state policies of developing a circular economy (Li et.al, 2007).

Circular Economy Promotion Law of the PRC

The purpose of the circular economy law in China is to promote the development of the Circular Economy by improving the resource utilization efficiency, by protecting and improving the environment and realizing sustainable development (lawinfochina, 2008).

China Association of Circular Economy (CACE)

CACE is a Chinese nationwide organisation that crosses different regions and spans various industries. It was approved by the Ministry of Civil Affairs and renamed from its original name. CACE carries out the fundamental state policy of resource conservation and environmental protection and implement the Law on Promotion of the Circular Economy (CACE, 2019).

Although many would China is not a good example of the adoption of data science and the circular economy, few can deny that they have been one of the initiators of writing the circular economy into their laws. Some countries are following their lead and other countries are learning from their mistakes and then develop their own practices, but it allows this thesis to have some foundations from a country who are practicing the need for standardizing the circular economy.

The author's own sources have been largely based on years of experience certifying products and management systems, addressing the issues good and bad in the standardisation process which has led to identifying the gaps and needs for environmental product standards and in particular a standard for the circular economy. The tentacles of the circular economy are far reaching which made the collaboration with data science a good match and uniquely a lacking area in the standardisation process. The collaboration was appealing and thankfully there is enough known knowledge and research to develop this thesis. Both data science and the circular economy have been rapid growth areas, so surprising that standards addressing best practice in these areas are lacking. The author's own examples have been a source of inspiration and based on true to life experiences either actual or potential. There have been many literature sources that have looked promising in their heading, but the detail did not transfer into useful information. However there has been enough to build a framework for this research.

2.1 Summary

The literature review supports the aims and objectives of the research, with key reports from the EM foundation. In the earlier years of this thesis research, it was difficult to find relevant research papers on the circular economy and data science and more difficult to find research papers stressing the need for standards. This is changing in the latter years from 2018 to present with more and more researchers including standards as a necessity for the transition to a circular economy or as a gap that needs to be filled. Majority of the literature sources were from journals as opposed to books. Research done by Pesce, et al "Circular Economy in China" characterized six sets of principles from six different established sources (British Standards Institution, Circle Economy, Ellen MacArthur Foundation, Suarez-Eiroa et al, Weetman, C and Tonelli, M and Cristoni, N), see Appendix. The six sets of principles portrayed different interpretations of what a CE principle should be, some of them overlapped others and were named differently although very similar but the span of what was presented demonstrated how diverse the CE is. The growing importance of the environment and its sustainability will lead to an acceleration of research in data science and its impacts on the circular economy.

The literature review led to the four research questions developed in Chapter 4 and gave good insights into the future acceleration of data science in the environmental sector. This leads onto the methodology used.

CHAPTER 3

METHODOLOGY

This research will look to present the information required to make this Standard happen without writing a publishable standard. The research will extend the current model on the Circular Economy through research into areas of: Data analysis, restriction of harmful chemicals so they are removed from the supply chain, research into local value creation (LVC), research into sustainable development in the circular economy and much more.

The Methodology approach is – a "**mixed methodology**" which will combine quantitative methods (data analysis) and qualitative data (case studies). This is the best fit of research methodology to answer the research questions identified in the Literature Review.

Methodology Approach

Mixed methodology – is a research approach made popular in the social, behavioural and health sciences in which researchers collect, analyse and integrate both quantitative and qualitative data together in a single study to address their research questions.

The specific mixed methodology design used in this thesis is 'embedded design'. Embedded Design – is a study based primarily on one data type being supported by another data type that plays a secondary role. The observation here is that one data type is not enough to answer all the research questions and that another data type is required. In research that is largely quantitative, qualitative data will provide support and the reverse is also true (Creswell, 2014).

Specific Methods

1. Data Collection – the data will be collected through the literature review, internet research and case study analysis of The Ellen MacArthur Foundation and the Circular Economy in China. The data collected from the literature review will drive the four research questions in Chapter 4.

2. Data Analysis - each section will include data for data analysis specific to the research questions. The data for analysis will support the main subjects of Standards development and the Circular Economy. Data scientists who understand and use this approach generate deep insights and then use their specific subject matter expertise to formulate exactly what those insights mean with respect to the area they have expertise in. Most of the current research/reports do not display the raw data from claims made and the data is not analysed or critiqued. The quantitative methods sections will be used:

   *To analyse data on raw materials being used that we are likely to run out of.

   *To analyse the main ingredients of "The Circular Economy" (re-using, repairing, refurbishing, and recycling).

   *To critically review the list of referenced Journal reports

   - to search more related journal papers (currently 40-50)
   - read reports and write a Literature Review

   *To review the body of regulations/standards that is related to elements of "The Circular Economy".

   *To analyse data on the REACH SVHC List.

   Data analysis tools to be used are "R", Excel, and Statistical Tools – the output from these tools are word clouds, charts – box plot, histogram, pie chart.

   The qualitative methods sections will be used:

   *To do a qualitative analysis (Case Study) on "The Circular Economy in China". China is the only nation to write the circular economy into law and to fully adopt Circular Economy practices.

   *To do a qualitative analysis (Case Study) on "The Ellen MacArthur Foundation". The Ellen MacArthur Foundation is a registered charity pioneering positive thinking to build the future through the framework of a circular economy.

*To do a qualitative analysis (Case Study) on "Recycling Technologies Ltd". Recycling Technologies is a forward-thinking company using modern technology and circular economy concepts to address the plastic crisis.

Research Plan

The proposed research will develop a Gantt Chart Project Plan of actions.

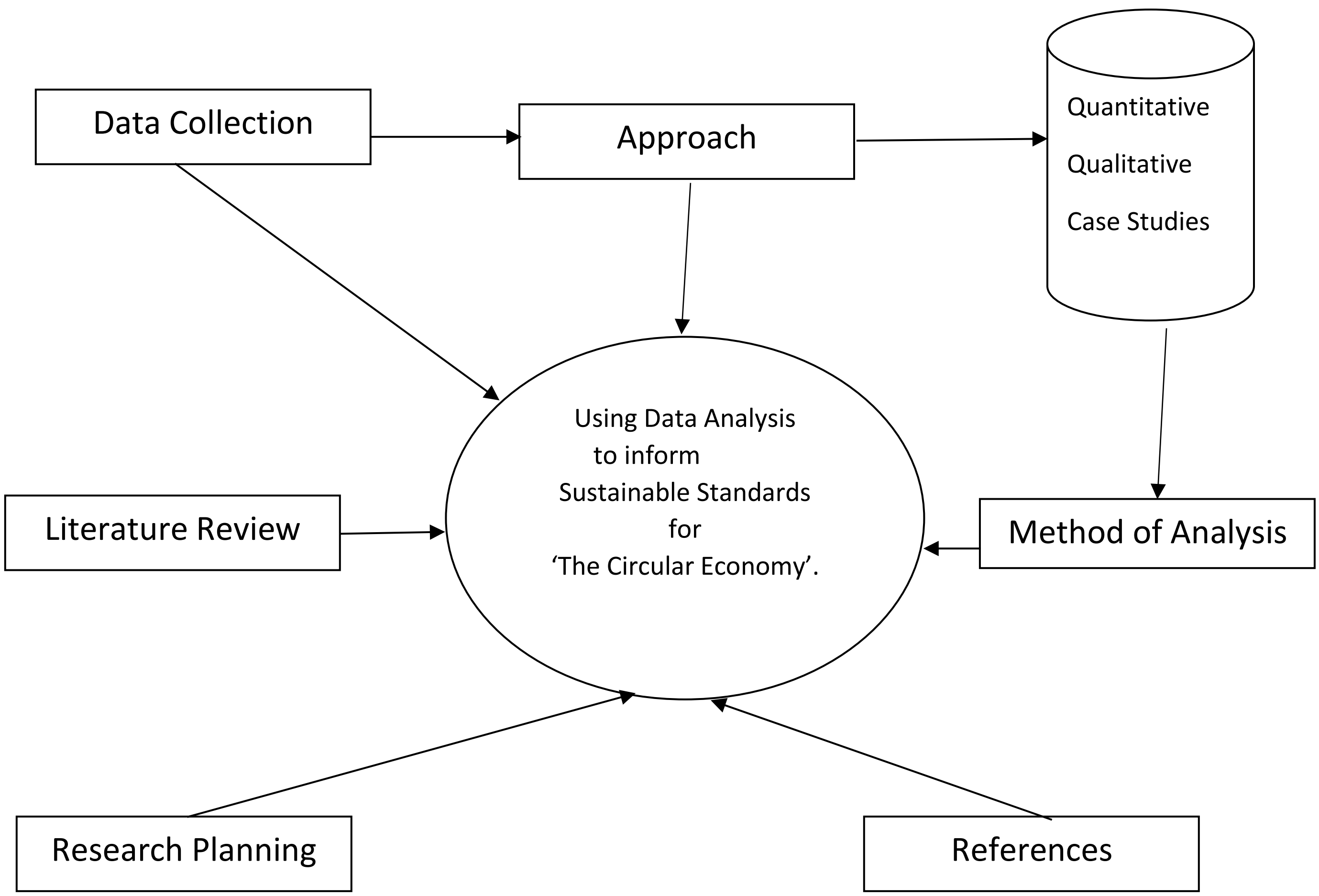


Figure 3.2: Research Plan

The research plan develops a doctoral project with realistic goals that are achievable within the project timetable.

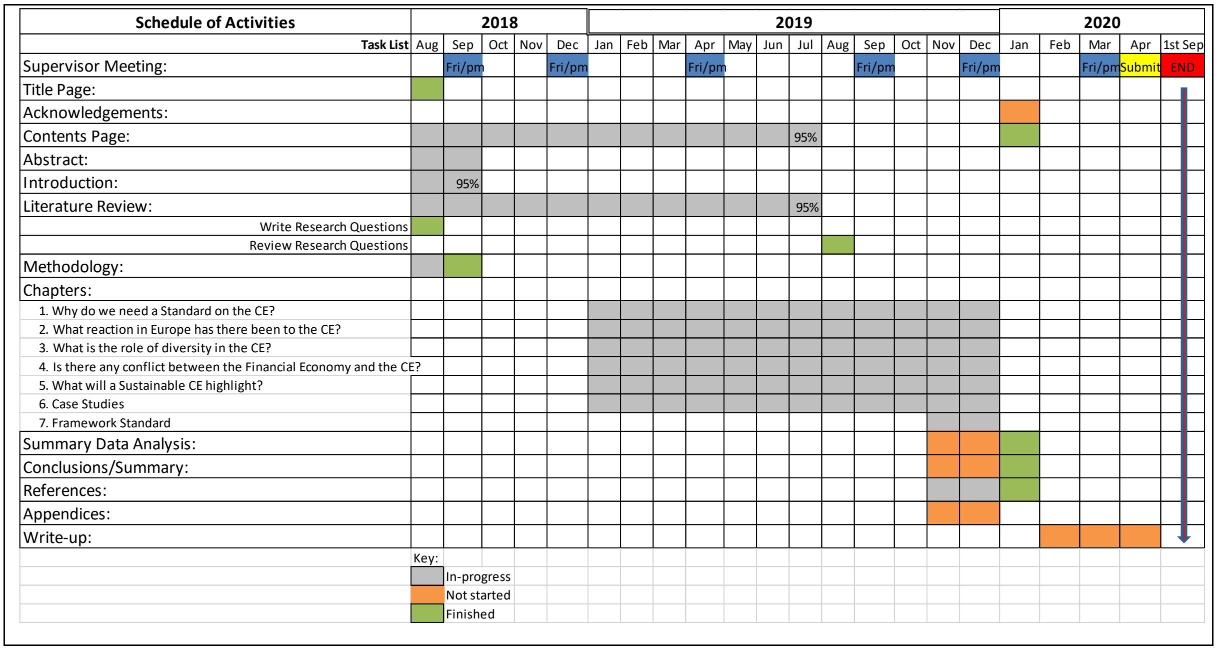


Figure 3.3: The Thesis Gantt Chart

Figure 3.3 above represents the author’s Gantt chart or project plan; this plan has been revised several times due to different circumstances. A thesis structure is in the Introduction, Figure 1.4.

Dataset Scoping Study:

As Data and the analysis of data is essential to this thesis here are some basics on Data and Data Science. Data can be collections of objects and their attributes as seen in Figure 3.4 below. This can be:

- rows of data (e.g. records of shops on a famous street)
- data objects (e.g. a person or a transaction), can consist of several attributes (e.g. an inherent part of someone or something)
- attributes describe the data object (e.g. the variables)

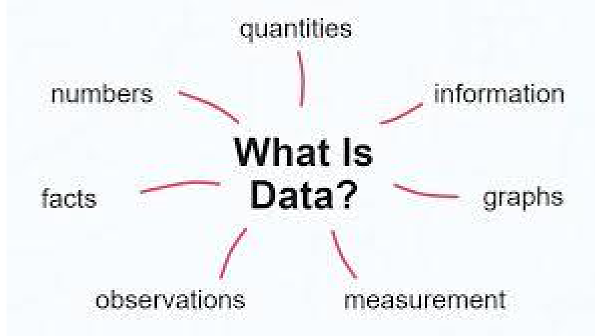


Figure 3.4: What is Data? (What is Data, 2020)

Types of Data

Data, Big Data, Data science and business analytics use structured, semi-structured and unstructured data.

Structured Data – is data that adheres to a pre-defined data model and is therefore straightforward to analyse (bigdataframework, 2020). This includes data contained in databases and spreadsheets e.g. sales data, financial records, lists etc.

Semi-structured Data – is data a form of structured data that does not conform with the formal structure of data models associated with databases or other forms of data tables but contains tags or other markers to separate semantic elements and enforce hierarches of records and fields within the data (bigdataframework, 2020). Semi-structured data sits between structured and unstructured data, e.g. word processing software, CSV, XML, NoSQL databases.

Unstructured Data – is data that either does not have a predefined data model or is not organised in a predefined manner. Unstructured information is typically text heavy, but may contain data such as dates, numbers and facts (bigdataframework, 2020). These inconsistencies make it difficult to analyse this form of data with traditional computer programs. Examples of unstructured data are photos, videos, social media files, power point presentations etc.

The types of data discussed above are displayed in Figure 3.5 below. Most of the data used in this thesis is structured data.

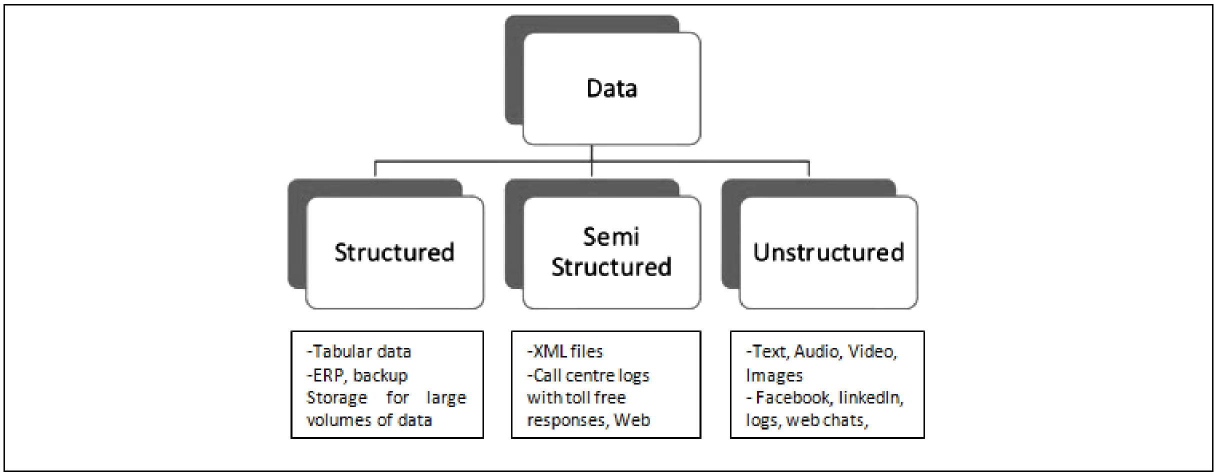


Figure 3.5: Types of Data (Tanwar, 2015)

Data Science

Data science is the study of data where you use techniques to collect, prepare, input, process, output/interpret and store data with the intention of obtaining useful information from it.

According to Dhar (2013) data science is the study of the generalizable extraction of knowledge from data or put in simpler terms maybe it is - a collection of methods and processes to explore real world problems with data, these may include actions like – collecting data, cleaning data, storing, and analysing the data. The point is to use data to inform decision making.

Dhar (2013) implies a focus involving data by extension, statistics, or the systematic study of the organisation, properties, and analysis of data and its role in inference, including our confidence in the inference. Figure 3.6 is a diagrammatic representation of a typical data science process where raw data is processed through continuous stages and transformed into actionable information that decisions can be based on.

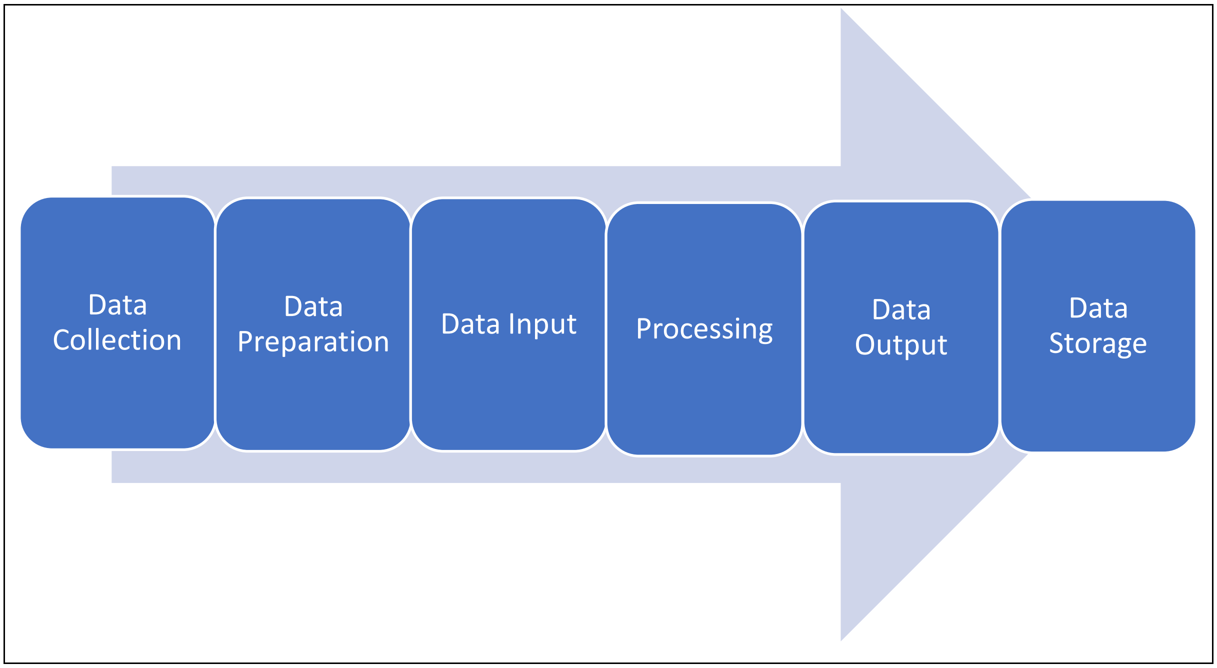


Figure 3.6: A Typical Data Science Process

Data Science is the scientific domain that is dedicated to knowledge discovery via data analysis (Pierson, 2017). Domain in this context refers to the industry sector or subject matter domain that data science methods are being used to explore (Pierson, 2017). Data science is easier to understand when you can describe its usage and user. Users of data science, namely data scientists have expertise in maths, statistics, computer programming and one or more subject matter domains. Having these skills allows data scientists to analyse large datasets, big data, interpret and predict analytics and forecast future events, utilise other computer science techniques like machine learning and artificial intelligence.

Data Science, including different statistical machine learning techniques is a tool that will see increasing use in efforts to tackle sustainability challenges (Balaprakash, 2021).

Within the six stages of the data science process, typically represented by Figure 3.6 specific data process elements can be identified including data wrangling, merging, exploratory data analysis (EDA), knowledge and information generation and requirements specifications. To process the data, the collected data follows the stages or a combination of the stages as applicable. It is important that the collected data is processed correctly to ensure accurate outputs from the data.

1. Data Collection – data is collected from available sources, these can be surveys, interviews, observations, focus groups, experiments, field trials and secondary data analysis. Data does not have to come from a single source, it can come from several sources and often using a combination of relevant sources is a better way to address a topic or subject area. An important consideration for data collection is the data quality and trustworthiness of your data as this will contribute positively to the data output.
2. Data Preparation – after the data is collected it can then be prepared, this stage is often referred to as the "pre-processing". During preparation the data is cleaned and checked for any errors. An indication of when the data needs to be cleaned is when it contains incomplete, inconsistent, and missing data. Data wrangling is the process of manually converting or mapping data from one 'raw' form into another format (Shah, 2020). Data wrangling is an important step in cleaning data.
3. Data Input – after preparation the data is inputted into destination systems like Enterprise Resource Planning (ERP), Material Requirements Planning (MRP), Customer Relationship Management (CRM) or a data warehouse and translated into compatible language it can understand.
4. Processing – data processing involves data parsing, recoding of variables, concatenation (the action of linking things together in a series) and reformatting.

   Data Analysis is the process that refers to hands on data exploration and evaluation (Shah, 2020).

   Exploratory Data Analysis (EDA) is an approach that postpones the usual assumptions about what kind of model the data follows with the more direct approach of allowing the data itself to reveal its underlying structure in the form of a model (Shah, 2020). EDA prescribes how to compartmentalise a dataset by sectioning what to look for, how to look and how to understand the outcomes. EDA does not define a formal process with a strict set of rules to follow, it allows you to explore the possible outcomes and home in on the ones that are realistic. EDA is fundamentally a creative process, but understanding the data needs this exploratory aspect to enable meaningful and beneficial decisions to be made from the data. Grasping this idea formulates the overall objective of EDA which is to obtain vital insights into the data.

Regression Analysis is a process for estimating the relationships among variables (Shah, 2020).

Data Mining is about understanding the nature of the data to gain insight into the problem that generated the dataset in the first place, or some unidentified issues that might arise in the future (Shah, 2020).

Data Blending is the process where big data from multiple sources are merged into a single dataset.

Data Merging is the process of combining two or more comparable data sets into a unified dataset or data warehouse.

5. Data Output – is the information resulting from processing the data, this stage presents the data in usable formats like plain text, charts, diagrams, graphs, videos. The information is displayed through a computer monitor or similar device.

   Data Visualisation is the graphical representation of information and data using charts, graphs, plots, infographics and sometimes animations. To convey the meaning and significance of the data it is critical to know the target audience for this data. There are plenty of data visualization tools available for example, Tableau, Infogram, ChartBlocks, Datawrapper, D3.js, Google Charts, FusionCharts, Chart.js, Grafana, Sigmajs and Polymaps.

6. Data Storage – allows for storage of the processed data ready for current or future use. Correctly stored data has become a requirement for compliance with regulations for example General Data Protection Regulations (GDPR). The most frequently used types of storage are:

   – direct attached storage (DAS), examples of DAS are USB flash drives, microSD cards and plug and play external hard drives.

   – network attached storage (NAS) are dedicated file storage that enables multiple users and client devices to access the data from a centralized storage unit. NAS devices would typically be found in homes and small businesses.

– storage area network (SAN), these are interconnected drives and servers that act as centralized pools of disk storage, that are standalone networks dedicated to data storage.
– cloud storage or remote storage transfers and accesses data off-site outside the local network using the internet. Cloud storage options have become very popular among business wanting to save on storage costs and space. Examples of cloud storage sites are Microsoft OneDrive, Google Drive, Dropbox, Box and iCloud.

At the end of the processing stages once the data is stored it is very important to protect the data and provide and update data security. Data security is a large topic so it will only be referred to here.

Santschi's article states that data and robust metrics play a critical role in developing and monitoring the progress towards the circular economy (Santschi, et al, 2022). The data gathered from the RFID implants in products exemplifies how useful this data is in the transition to a circular economy. The data science process provides a rich source of output information for organisations that need it to perform their operations in a circular economy, for example recyclers who need to know what is in their products. Another example is the data catalogue created by Giz Data lab that summarises some of the most important datasets related to the circular economy transition. The data catalogue contains thirty-four resources that cover different geographic areas and harness a variety of technology-based data collection techniques. It allows users to either skim the available data or find specific information relevant to their individual circular economy project (Santschi, et al, 2022). Shah presented an example of how regression analysis is used to study the effects of carbon emissions on bringing about the earth's climate change. The increased amount of waste going to landfill sites and the increased consumption of fossil fuels is increasing the amount of CO_2 in the atmosphere which is resulting in the overall change in temperature. The transition to the circular economy will reduce the waste problem but having reliable data to analyse is crucial for organisation having to meet their due diligence targets of reporting these metrics.

The transformed raw data can then be depicted in the Information Hierarchy in Figure 3.7 - Data Transformation - Data – Information – Knowledge – Wisdom. For many data-starved areas of inquiry, especially health care and the social, ecological, and earth sciences, data provides an unprecedented opportunity for knowledge discovery and theory development. Dhar concludes that "never have these areas had data of the variety and scale available today" (Dhar, 2013).

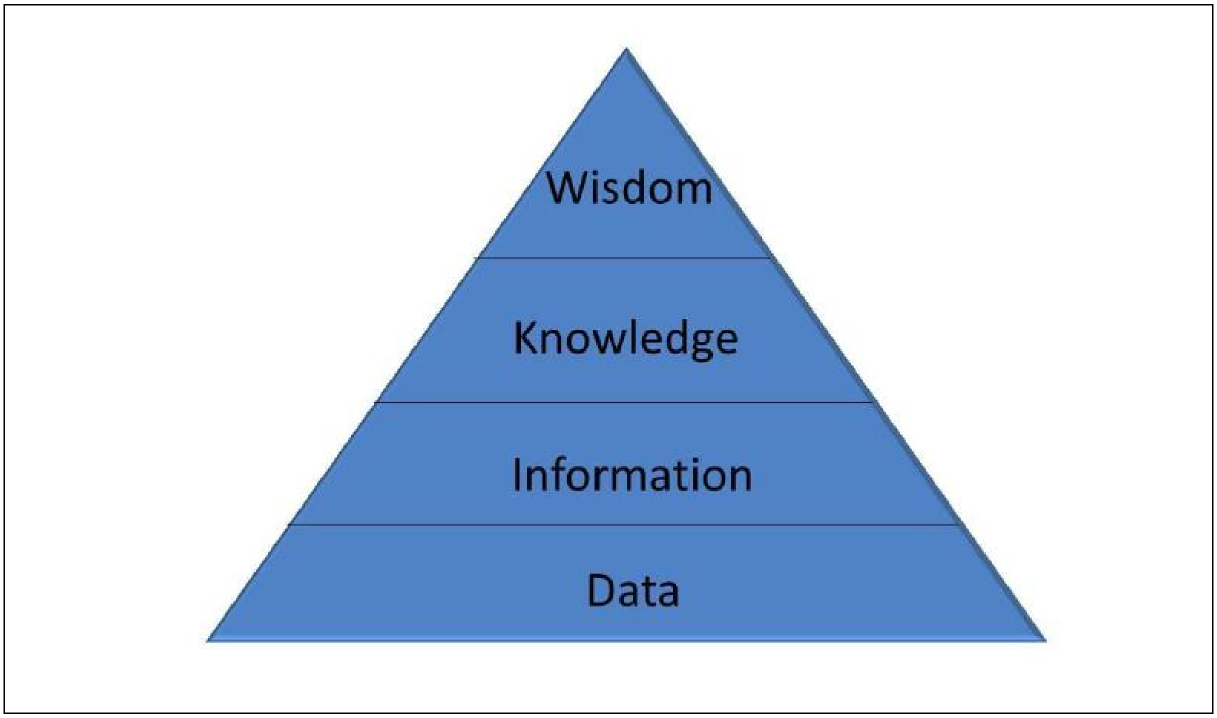


Figure 3.7: The Information Hierarchy (The Information Hierarchy, 2020)

To date, there has been little work on data science applied to the understanding and management of the natural environment (Blair et al, 2019). This is surprising, because environmental studies are enormously data intense with a need for new technology to access the massive amount of data being captured about the natural environment and because climate change is such a phenomenal challenge that data scientists would see this as an area of great opportunity. Some research makes significant claims but do not display the raw data from claims made and the data is not analysed or critiqued.

3.1 Summary

The ‘mixed methodology’ approach and the mixed methodology design - ‘embedded design’ allows the combination of quantitative and qualitative data to be mated in this thesis. The theme from the title of the thesis means both these data forms of primary and secondary data could be intertwined to inform this thesis.

It is often said that there is a data science skills gap in the world, but there is a greater gap with combining data science and the circular economy and generally in the environmental sector. More university courses are being developed and offered to try and fill this gap, they can provide some knowledge and more courses will be developed in the future. The data science tools used here to model Horizon 2020 applications show there is an increase in CE projects, and we are constantly hearing of the impacts climatic changes are having on the planet and so it is correct to highlight these. A CE data centric standard when developed will include all these areas and have the added protection of being updated or amended as standards get reviewed every five years. The next chapter details the main research findings of this thesis.

CHAPTER 4

RESEARCH FINDINGS and ANALYSIS

Introduction

This Chapter will research the main findings and analysis to the Circular Economy. It will cover the research questions from the Literature Review. As the Legislative/Standards activities have been led by the European Commission (EC) this Chapter will research the progress the EC is making in tackling the transition towards a Circular Economy. The implementation of a Circular Economy strategy to eliminate waste and create a closed -loop system for regenerating the continual use of resources in order to preserve our natural resources has been thought and talked about for many years. This chapter will highlight how standardisation will move this forward. The case studies will give further assurance what has been done and a framework standard will set the template for future work.

4.1 Why is there a need for a Circular Economy Standard?

4.1.1 Introduction

The European Commission created a legislative proposal on waste in December 2014, named - Towards a Circular Economy: A zero waste programme for Europe. Which they subsequently withdrew with a commitment to use its new horizontal working methods to present a new package by the end of 2015 to cover the full economic cycle rather than just waste reduction targets. The European Commission adopted this revised action plan in 2015 with the belief that it would accelerate Europe's transition towards a Circular Economy, boost global competitiveness, promote sustainable economic growth and generate new jobs. Many other organisations including the international standards developers ISO and IEC have seen rising demand for standards to address the increasing issues that the CE will address. ISO declared that while standards and initiatives abound for components of the CE, such as recycling, there is no current agreed global vision on how an organization can complete the circle (Naden, 2019). In May 2021, the IEC agreed to progress a new project that addresses e-waste. E-waste does not stop at national or regional borders. There is a need for a worldwide joint approach to the treatment and preparation for the reuse of e-waste (Mauyal, 2021). The massive increase in consumerism and the waste generated by it meant that waste has become a big problem. So, the Circular Economy intends to address this, and this research uses data analysis and standardisation as the means.

4.1.2 Key Factors

Three key factors mentioned here are: Critical Raw Materials, Ozone Depleting Substances and Population Increase, but there are many other factors that could be included that are impacting the environment and can be significantly reduced by the circular economy, standardisation and data science.

4.1.2.1 **Critical Raw Materials**

Raw materials are essential to our everyday lives. Millions of jobs rely on the availability of raw materials. The EU's raw materials policies aim to help raise industry's contribution to EU Gross Domestic Product (GDP) to around 20% by 2020.

In a world where humans occupied just a small part of the global eco-system the concept of unlimited production seemed possible mainly because the facts were not available (it was theoretical). A few decades later and this proportionate figure has dramatically increased, and we reached a point in 2010 (according to Global Footprint, Annual Report 2012) when the overall needs exceeded more than 50% of the regenerative capacity of the earth. This means that the continuation of current levels of extracted resources from the environment, the increase in production and failure to reduce our waste is making it impossible to achieve sustainability. The research in the annual report 2012, "The European Economy: from a Linear to a Circular Economy" based on 2011 data, shows that if all the people on Earth would live as a developed country citizen, then we would require 4.1 Earths. This is perfect reason for a standard(s) on the Circular Economy.

Human demands on the planet exceed supply.

- Humanity's Ecological Footprint exceeded the Earth's biocapacity by more than 50%in 2008.
- In recent decades, the carbon footprint is a significant component of this ecological overshoot.

- Biocapacity per person decreases from 3.2 global hectares (gha) in 1961 to 1.8 (gha) per capita in 2008, even though total global biocapacity increased over this time.
- Rising consumption trends in high-income groups around the world and in BRIICS countries, combined with growing population numbers, provide warning signs of the potential for even larger footprints in the future (Living Planet, 2012).

The rapid economic expansion of BRIICS group of countries (Brazil, Russia, India, Indonesia, China and South Africa) requires special study with regards to ecological footprint and human demands but is not intended in this thesis.

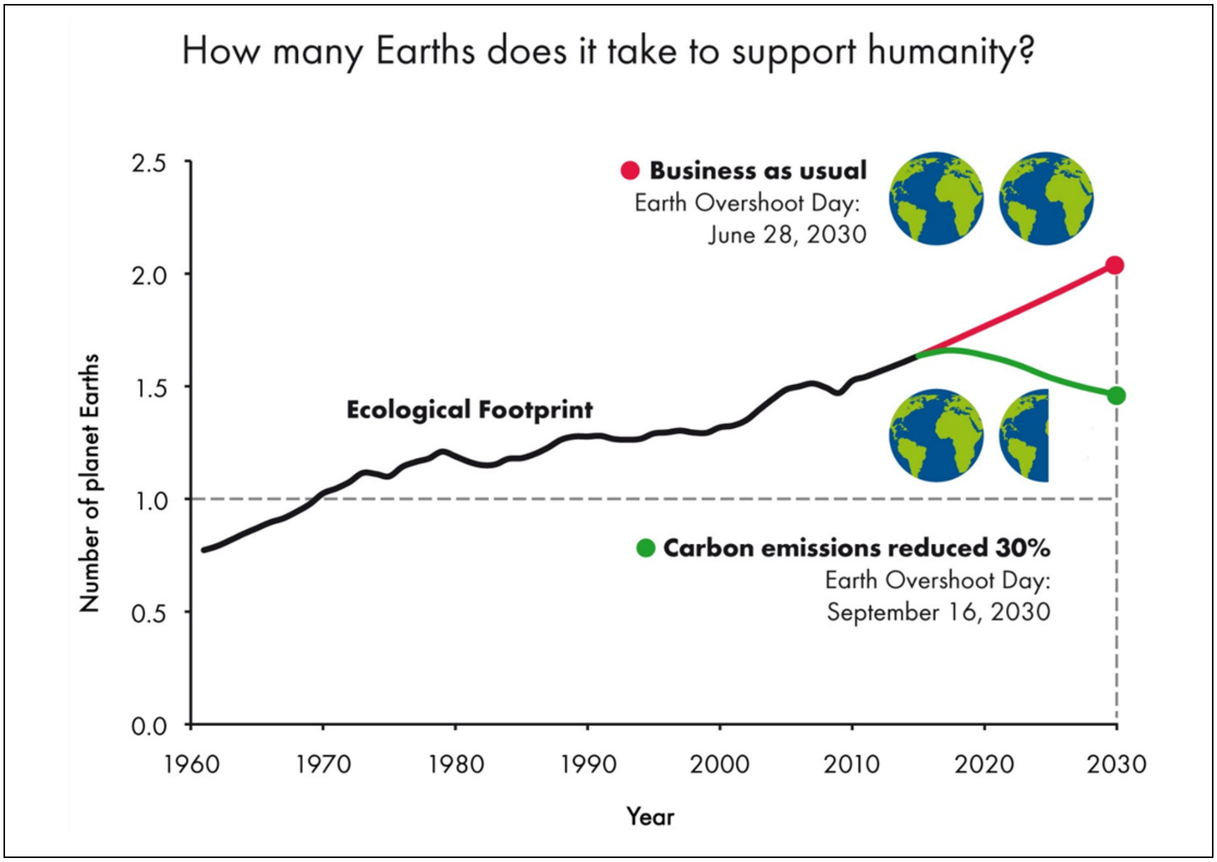


Figure 4.1: Ecological Footprint – How Many Earth's (Footprint Network, 2012)

Our current usage is equivalent of 1.6 earths to provide the resources we are absorbing (Footprint Network, 2012). According to Figure 4.1 we are exceeding what we can sustain in our resource usage, and we need to do something about that. More will be said about the ecological footprint in later chapters.

The diagram, Figure 2.3 in Literature Review, from the EU's website shows the initiatives the EU are focusing on- namely the Raw Materials Initiative, Horizon 2020 and the European Innovation Partnership. The focus here in line with this thesis is on non-food and non-fuel raw materials, both primary sourced from mining and forestry and secondarily sourced (from e.g., recycling). Generally available raw materials: Apart from biomass, generally available raw materials are the raw materials that nature needs for life (iron, silicon, carbon, magnesium, sodium, potassium, calcium, nitrogen, oxygen, phosphorous, sulphur, hydrogen). This preserves the natural capital and enables us to make our economy more future -proof and less dependent on imported fossil sources.

The EU Commission has identified twenty critical raw materials listed because of their risks of supply shortage and their impacts on the economy are higher than the other raw materials. The chart indicates clearly that China is the most influential in terms of global supply of the twenty critical raw materials. The risks associated with concentrated areas of production are in many cases compounded by low substitutability and low recycling rates. A list of these twenty critical raw materials can be found in the Appendix of the EU's review document (European Commission, 2014). The critical raw materials list was updated in 2015 and now includes forty-one materials or material groups that are at risk, but we need to maintain our economy and lifestyle. A list of these forty-one critical raw materials can be found in the Appendix (BGS Risk List, 2015).

4.1.2.2 **Ozone Depleting Substances**

Ozone (O_3) is an unstable form of oxygen; it is very unstable and when formed around the earth's crust it can cause pollution problems. The Ozone layer by contrast is one layer in the stratosphere that acts as a shield for life on earth by trapping ultraviolet radiation. The Ozone layer is getting thinner and being damaged. Damage to the Ozone layer is being caused by chemical compounds called Chlorofluorocarbons (CFCs). CFCs are commonly found in society, mostly used as refrigerants, propellants for aerosols and in plastic products. They stay in the atmosphere for a long time and slowly diffuse upwards until they reach the stratosphere. Upon reaching the stratosphere they react with ozone and start depleting it. The Appendix has a List of Ozone Depleting Substances.

Table 2 lists the raw materials that have become scarce and the levels of scarcity because of our current linear model. At some point the demand for these resources will outweigh what is available.

Scarcity	**Mineral**	**Total World Extraction (2004-2013)**	**Extractable Global Resources**	**Total Extraction as a proportion of the EGR** (2004-2013)	**Scarcity***
Very scarce	Antimony	1,722,000	8,000,000	22%	10.8
Scarce	Molybdenum Gold Rhenium Zinc	2,211,000 116,000,000	60,000,000 2,800,000,000	4% 4%	9.4 10.2 9.1 9.5
Moderately scarce	Tin	2,724,000	220,000,000	1%	8.3
	Chromium	69,500,000	3,300,000,000	2%	8.6
	Copper	160,000,000	7,500,000,000	2%	8.8
	Lead	40,860,000	3,750,000,000	1%	8.2
	Silver	224,000	20,000,000	1%	8.2
	Arsenic	465,300	60,000,000	1%	7.7
	Bismuth	69,500	5,200,000	1%	8.6
	Cadmium	208,400	39,000,000	1%	7.5
	Iron ore (gw)	22,830,000,000	5,700,000,000,000	0.4%	7.9
	Nickel	16,510,000	1,800,000,000	1%	8.0
	Tungsten				
	Chromium	659,200	80,000,000	1%	7.9
	Boron (as	69,5000,000	3,300,000,000	2%	8.6
	B203)	41,330,000	1,900,000,000	2%	8.4
Not scarce	Aluminium				
	Magnesium	389,500,000	3,200,000,000,000	0.01%	3.7
	Beryllium	52,050,000	530,000,000,000	0.01%	3.6
	Barium	1910	120,000,000	0.002%	1.7
	Cobalt	42,802,525	22,000,000,000	0.2%	6.6
	Gallium	655,600	680,000,000	0.1%	6.1

	Germanium Mercury Indium Lithium Manganese Niobium Rare Earth Elements (REE) Platinum Group Metals (PGMs) Selenium Tantalum Strontium Titanium Vanadium	1692 1168 16,930 6585 4,587,000 132,000,000 579,400 1,211,000 4755 20,810 9908 4,126,000 100,370 642,400	680,000,000 64,000,000 2,7000,000,000 20,000,000 800,000,000 24,000,000,000 480,000,000 6,700,000,000 1,900,000 2,000,000,000 4,300,000,000 14,000,000,000 170,000,000,000 4,300,000,000	0.0002% 0.002% 0.001% 0.03% 0.6% 0.6% 0.1% 0.02% 0.3% 0.001% 0.0002% 0.03% 0.0001% 0.01%	-0.1 1.8 1.0 4.6 4.7 6.5 6.1 4.2 6.6 1.2 4.0 4.5 3.8

*Scarcity is expressed as Ln (1,000,000/exhaustion time after 2020).

Table 2: Scarcity of Rare Earth Elements

Rare Earth Elements (REEs) – are a group of seventeen chemical elements that occur together in the Periodic Table. The group includes Yttrium, Scandium and the 15 Lanthanide elements.

Platinum Group Metals (PGMs) – Platinum is one of a group of six chemical elements collectively referred to as the platinum group elements.

Platinum Group Elements (PGE) are very rare in the earth's crust. The abundance of platinum and palladium in the earth's crust are similar approximately 5 parts per billion (ppb), by weight. Rhodium, Iridium and Ruthenium are even scarcer at about 1 ppb (BGS Platinum, 2009).

Despite been referred to as being not scarce in the above table, this report from the British Geological Survey describes these PGE as being rare. PGE are sold in a number of forms including pure metal and a variety of compounds, solutions and fabricated products. The catalytic properties of the PGE, which is their main application are exploited in two main sectors: emissions control systems and process catalysts for industrial applications. By far the largest application of platinum is in auto catalysts as shown in the diagram Figure 4.2 below, which are used to convert noxious emissions (carbon monoxide, nitrogen oxides and hydrocarbons) from car exhaust systems to harmless non-toxic products. Demand for PGE in auto catalysts has grown considerably from the 1970's onwards as various countries have variable qualities of gasoline and platinum is preferred on account of its higher sulphur tolerance.

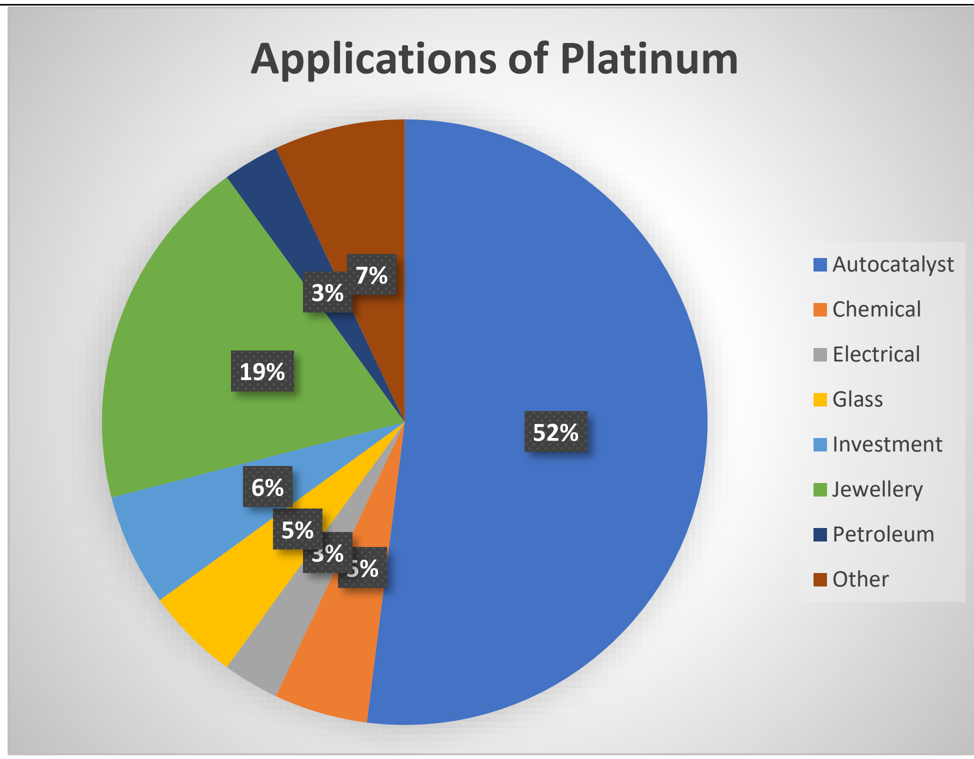


Figure 4.2: Applications of Platinum (redrawn from BGS Platinum, 2009)

4.1.2.3 **Population Increase**

The sevenfold increase of the world population over the course of two centuries amplified humanity's impact on the natural environment. To provide space, food and resources for a large world population in a way that is sustainable into the distant future is without question one of the large, serious challenges for our generation. The global population grew very slowly up to the 1700's – 0.04% (see Figure 4.3), however over the last 100 years the global population more than quadrupled.

Population growth is still fast; every year 140 million people are born, and 58 million people die – the difference is the number of people that we add to the population in a year is 82 million (ourworldindata.org).

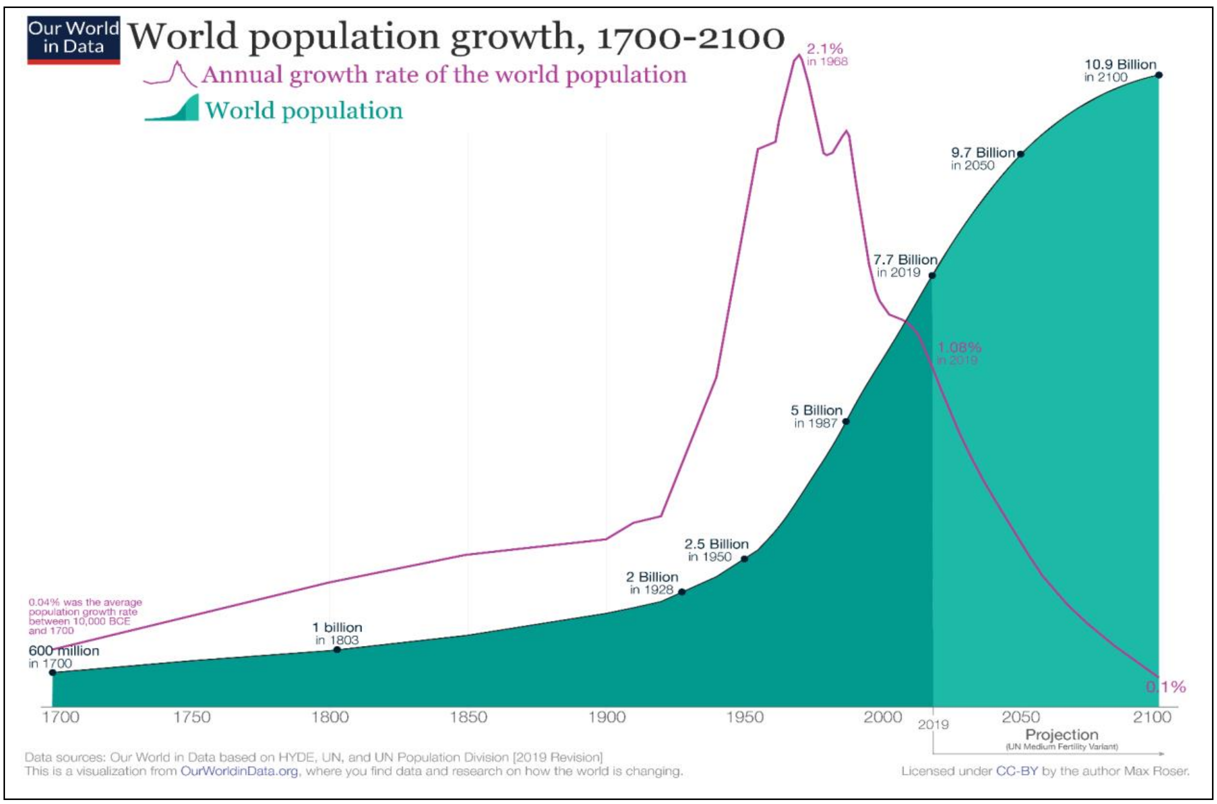


Figure 4.3: World Population Growth 1700 – 2100 (ourworldindata, 2019)

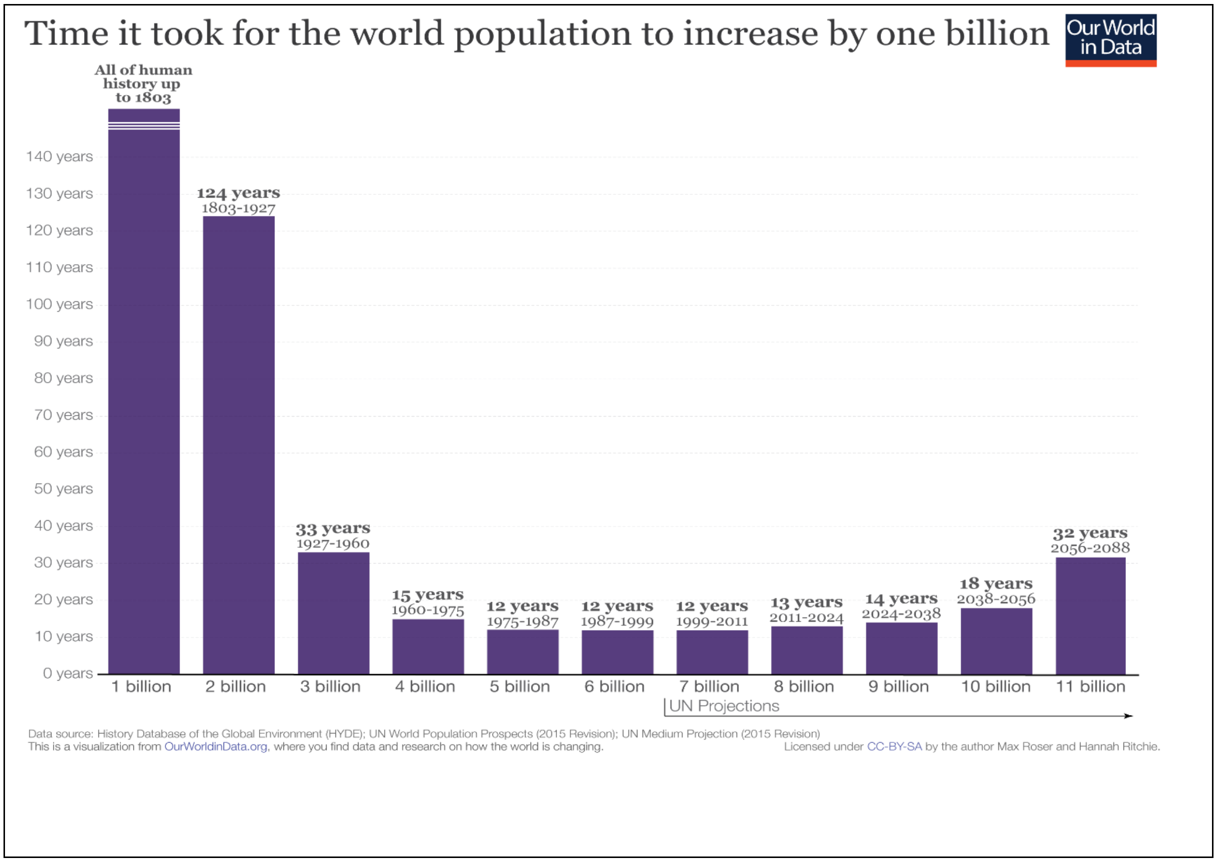


Figure 4.4: World Population Growth Increase (ourworldindata, 2019)

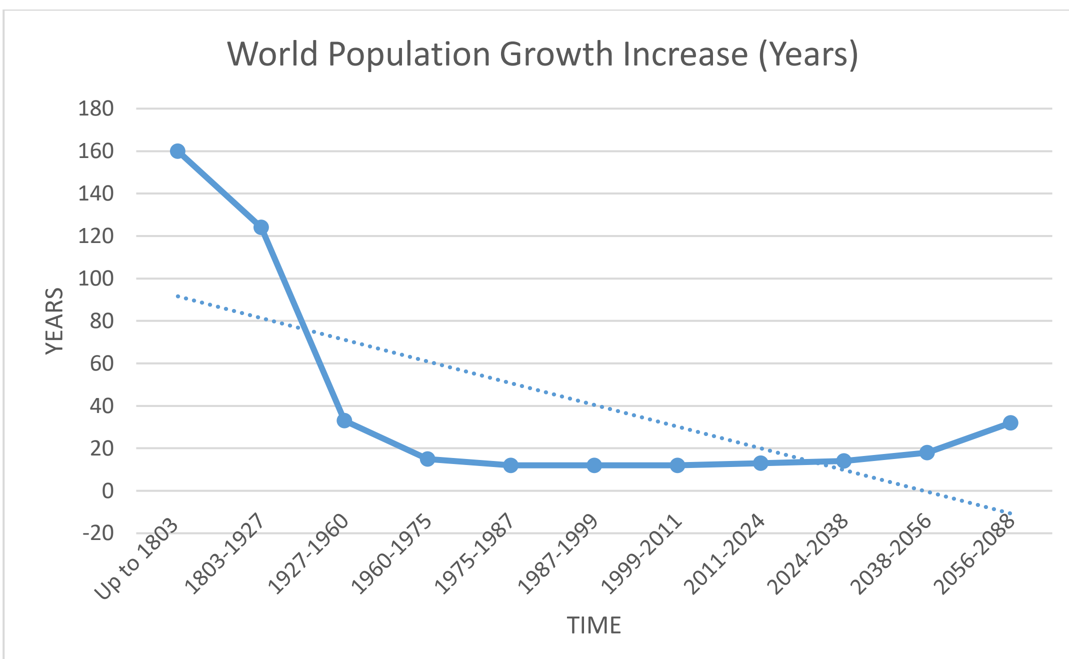


Figure 4.5: World Population Growth Increase (Years), (based on ourworldindata, 2019)

What is very interesting is that the trendline shows the predicted population growth/year decreasing to below zero but the overall population still increasing. More people on the planet means more resources are required to make more products, inevitably there will be more waste.

4.1.3 Waste Management

As the world's population, economy and consumption grows the accumulation of waste is going to get worse. The biggest problem that faced the organisers of the 2016 Olympic games in Rio de Janeiro was the hundreds of tonnes of unprocessed waste. This is not unique to Rio, because many big cities face similar problems. The amount of waste being produced has spiralled out of control, causing problems like contamination, pollution and in some cases disease. The continuation of such situations will eventually cause the deterioration of natural environments and eco-systems. Waste management is regularly perceived as a means of recovering resources and preventing environmental impact. "I always say when I go to cities, if somebody comes up with a magical solution for the waste management situation of the city, be scared about it," said Lillian Abarca-Guerrero of the Costa Rica Institute of Technology and Eindhoven University of Technology in the Netherlands.

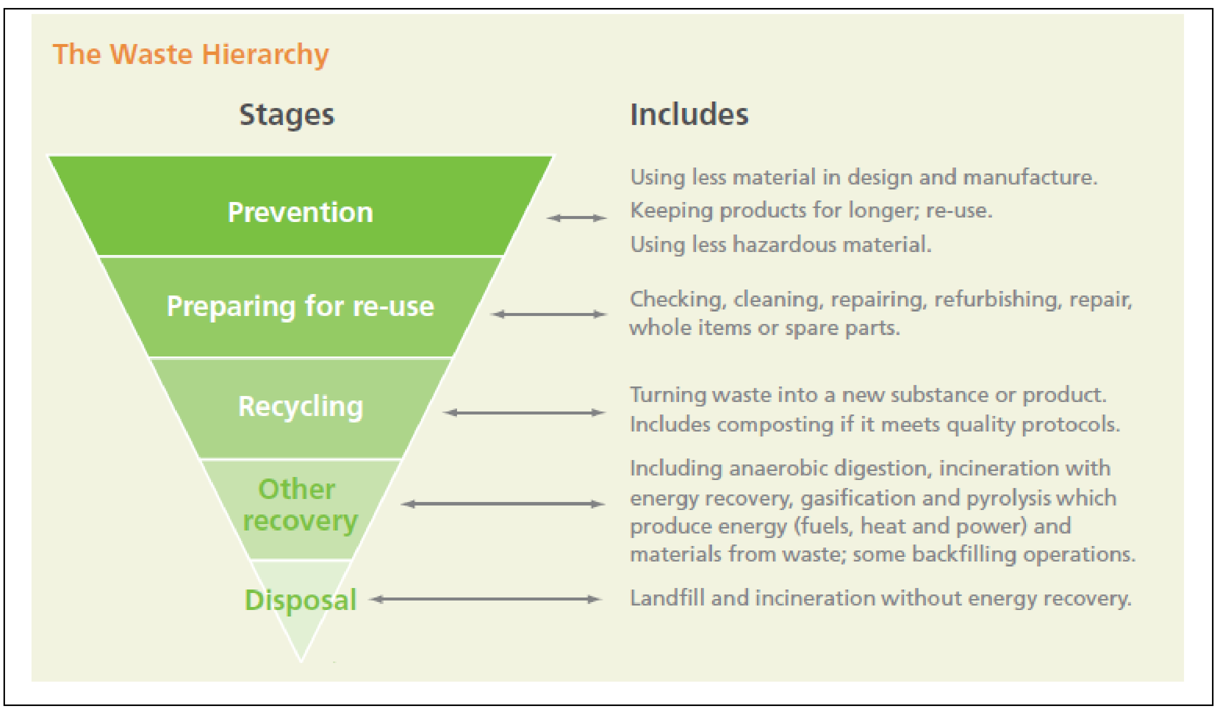


Figure 4.6: The Waste Hierarchy (Source: Defra, 2011)

The “Waste Hierarchy” Figure 4.6 ranks waste management options according to what is best for the environment. It gives top priority to preventing waste in the first place. When waste is created, it gives priority to preparing it for re-use, then recycling, then recovery and last of all disposals (e.g., landfill), (Defra, 2011). Compliance with the Waste Framework Directive means using the waste hierarchy in your waste management system. All of this is progressing towards the Circular Economy.

When it comes to waste, the Chinese Government have a more robust way of dealing with waste management; by writing it into their Circular Economy Promotion Law – Articles 9 and 10:

Article 9 – says Enterprises and public institutions shall set up management systems and take measures to reduce the consumption of resources, reduce the production and discharge of wastes and improve the reutilization and recycling level of wastes.

Article 10 – says Citizens shall enhance their awareness of resources conservation and protecting the environment, consume resources in a reasonable way and save resources. The state encourages and guides citizens to use products that save energy, water, and materials as well as environment-friendly products and recycled products to reduce the production and discharge of wastes. Citizens have the right to report acts of wasting resource and damaging the environment and have the right to access government information about the development of the Circular Economy and propose their opinions and suggestions (lawinfochina, 2008).

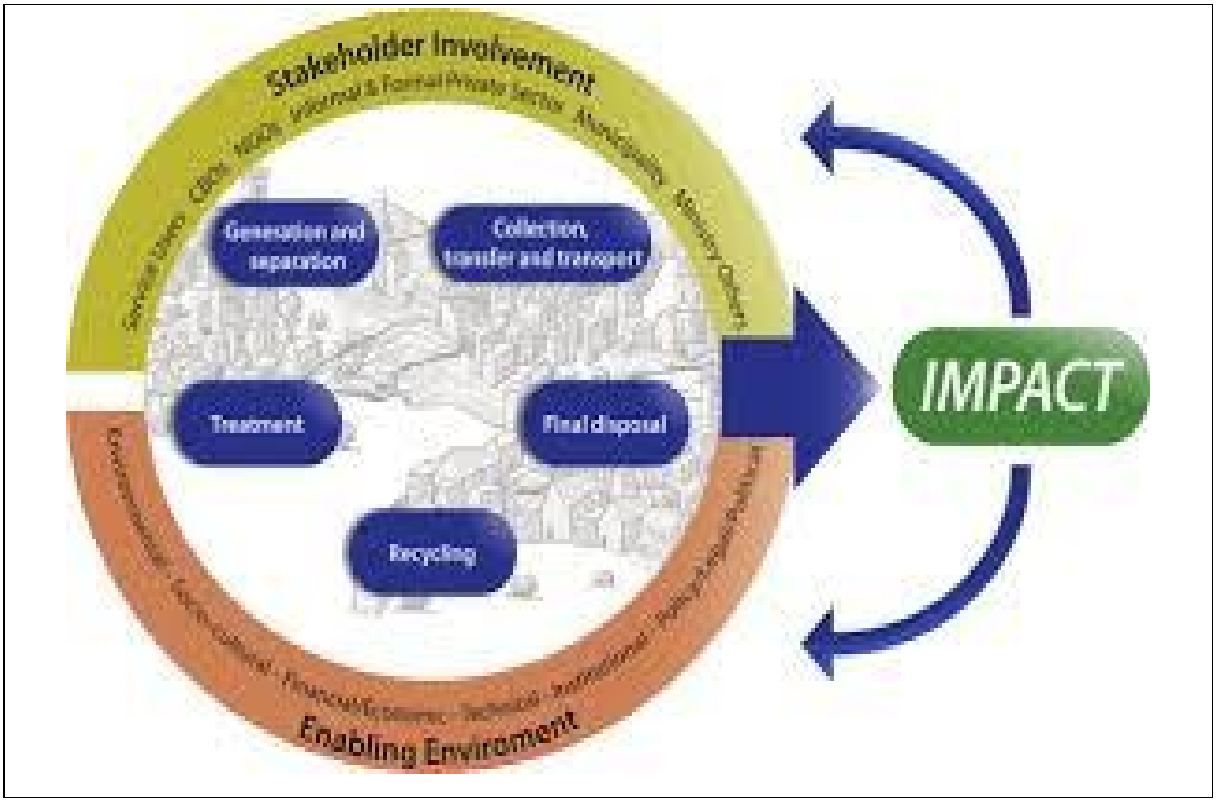


Figure 4.7: The Integrated Sustainable Waste Management Model (Source: Morgan, 2015)

There are no magical solutions in waste management. There are paths to follow for the prevention, reduction, reuse, recycle and safe disposal of waste. The waste management report outlines the stakeholders to be considered and the basic elements and aspects that must be taken into consideration for a successful waste management system. Figure 4.7 above illustrates some of these paths (Morgan, 2015).

In the past the creation of waste in connection with production and consumption was accepted as a necessary evil. Today, that apparent common sense is increasingly being challenged: circular economy, zero waste, closed-cycle, resource efficiency, waste avoidance, re-use, recycling – all these terms can be attributed to the ideal of achieving a world largely without waste, and instead one with a responsible attitude to resources, materials, products and the environment (EC 398, 2014).

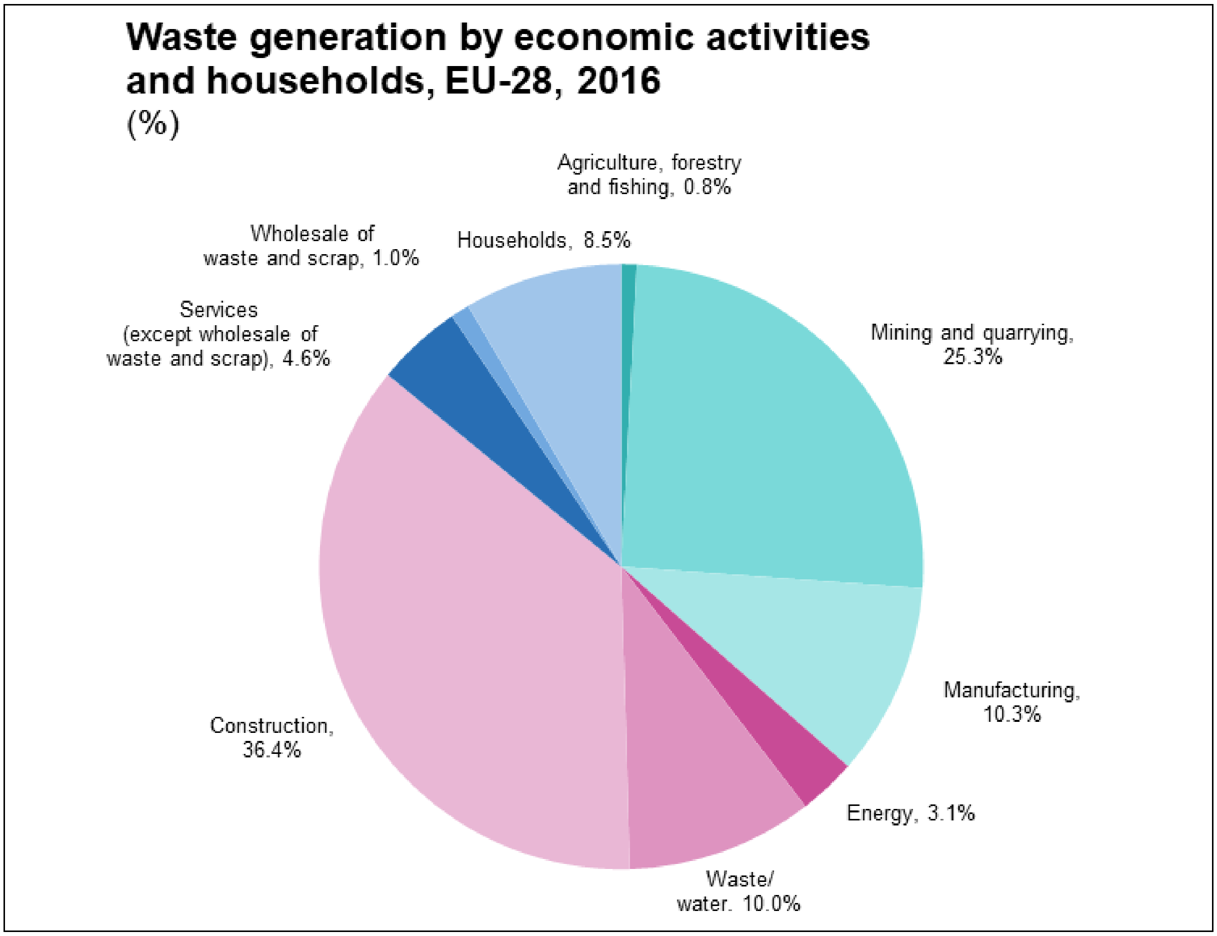


Figure 4.8: Waste Generation in the EU- 28 (Eurostat, 2016)

In the European Union, the overall waste generated is related to the population size and economic prosperity of the country. What Figure 4.8 above does not define is the country specific waste figures, but in 2016 the EU-28 countries generated 2,538 million tonnes of waste by all economic activities and households. That is a staggering amount of waste and when you factor in that the EU-28 countries recycling rate in 2016 was 55% (shown in Chapter 4), then you see the need for the Circular Economy. That is 1,142.1 million tonnes of unrecycled waste lying around Europe. In Figure 4.8, the construction industry is the highest producer of waste and the highest recycler of their own waste, but in other areas there are huge problems combating this much waste.

Waste management plays a central role in the Circular Economy: it determines how the European Union waste hierarchy is put into practice. The waste hierarchy establishes a priority order from prevention, preparation for reuse, recycling, and energy recovery through to disposal, such as landfilling. The way we collect and manage our waste can lead either to high rates of recycling and to valuable materials finding their way back into the economy, or to an inefficient system where most recyclable waste ends up in land fill or is incinerated, with potentially harmful environmental impacts and significant economic losses. To achieve high levels of material recovery, it is essential to send long-term signals to public authorities, businesses, and investors and to establish the right conditions at European Union level including consistent enforcement of existing obligations. (European Commission, 2015) Table 3 below shows that there is a long way to go with 45.7% of waste ending up in landfill.

Waste treatment, 2016
(% of total)

	Recovery			Disposal	
	Recycling	Backfilling	Energy recovery	Landfill and other	Incineration without energy recovery
EU-28	37.8	9.9	5.6	45.7	1.0
Belgium	76.9	0.0	12.6	6.4	4.1
Bulgaria	5.2	0.0	0.4	94.4	0.0
Czechia	49.5	29.0	4.5	16.6	0.4
Denmark	51.4	0.0	19.5	29.1	0.0
Germany	42.7	26.6	11.3	18.1	1.2
Estonia	21.6	11.2	2.5	64.7	0.0
Ireland	10.6	46.0	4.8	38.4	0.3
Greece	4.8	0.0	0.3	94.8	0.0
Spain	37.1	5.7	3.6	53.6	0.0
France	55.0	10.3	5.4	27.6	1.6
Croatia	47.2	4.0	1.0	47.8	0.0
Italy	78.9	0.1	4.0	14.2	2.7
Cyprus	10.4	28.0	3.8	57.8	0.0
Latvia	71.7	1.1	6.8	20.3	0.0
Lithuania	33.4	4.1	5.8	56.6	0.0
Luxembourg	34.8	24.2	2.1	39.0	0.0
Hungary	54.1	3.7	7.4	34.2	0.6
Malta	19.1	63.4	0.0	17.2	0.4
Netherlands	45.6	0.0	7.6	46.0	0.9
Austria	37.0	11.0	:	45.9	:
Poland	46.2	22.2	3.3	28.0	0.4
Portugal	43.5	9.5	12.1	34.7	0.2
Romania	4.0	0.4	1.4	94.1	0.1
Slovenia	60.2	27.2	4.8	6.9	0.8
Slovakia	40.0	4.7	7.0	47.8	0.5
Finland	7.4	0.0	4.5	88.0	0.0
Sweden	12.0	4.9	6.6	76.3	0.2
United Kingdom	48.5	7.8	3.4	37.5	2.7
Iceland	25.0	51.0	0.4	22.3	1.3
Norway	43.5	2.6	34.0	19.5	0.5
Montenegro	0.8	0.0	0.2	98.9	0.0
Serbia	2.8	0.8	0.2	96.3	0.0
Turkey	33.0	0.0	0.8	:	0.2
Kosovo (¹)	0.0	0.0	0.0	100.0	0.0

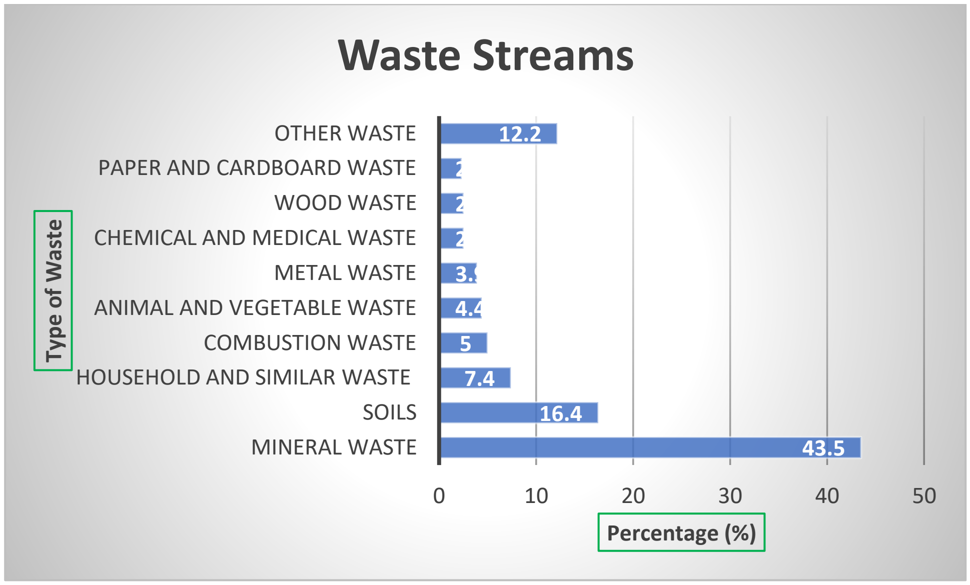
(¹) This designation is without prejudice to positions on status, and is in line with UNSCR 1244/1999 and the ICJ Opinion on the Kosovo declaration of independence.

Source: Eurostat (online data code: env_wastrt)

Table 3: Waste Treatment – EU-28 Countries (Eurostat, 2016)

In the last decades, green and sustainable supply chain management practices have been developed, trying to integrate environmental concerns into organisations by reducing unintended negative consequences on the environment of production and consumption processes. In parallel to this, the circular economy discourse has been propagated in the industrial ecology literature and practice. Circular economy pushes the frontiers of environmental sustainability by emphasising the idea of transforming products in such a way that there are workable relationships between ecological systems and economic growth. Therefore, circular economy is not just concerned with the reduction of the use of the environment as a sink for residuals but rather with the creation of self-sustaining production systems in which materials are used repeatedly. Through two case studies from different process industries (chemical and food), Genovese compares the performances of traditional and circular production systems across a range of indicators. Direct, indirect and total lifecycle emissions, waste recovered, virgin resources use, as well as carbon maps which provide a holistic visibility of the entire supply chain are presented. Genovese asserts that an integration of circular economy principles within sustainable supply chain management can provide clear advantages from an environmental point view. Emerging supply chain management challenges and market dynamics are also highlighted and discussed. Genovese questions how sustainable supply chain management can be enhanced by aligning it to the circular economy concept? and what are the environmental implications of circular production systems in terms of carbon emissions, resource use and waste recovered when compared to a linear production paradigm? (Genovese, et al, 2015).

Whilst it is true that all waste streams should be included regardless of whether they are from households, businesses, industry, mining or the construction industry, this research does not include food waste.



Waste Streams by Type of waste

Type of waste	Percentage (%)
Mineral waste	43.5
Soils	16.4
Household and Similar waste	7.4
Combustion waste	5
Animal and vegetable waste	4.4
Metal waste	3.9
Chemical and medical waste	2.5
Wood waste	2.5
Paper and cardboard waste	2.3
Other waste	12.2

Figure 4.9: Waste Streams by type of waste (Eurostat, 2016)

The data for the above chart Figure 4.9 and spreadsheet was sourced from (Eurostat, 2016).

The revised legislative framework on waste entered into force in July 2018**.** It sets clear targets for reduction of waste and establishes an ambitious and credible long-term path for waste management and recycling.

Key elements of the revised waste proposal include:

- A common EU target for recycling 65% of municipal waste by 2035;
- A common EU target for recycling 70% of packaging waste by 2030;
- There are also recycling targets for specific packaging materials:
  - Paper and cardboard: 85 %
  - Ferrous metals: 80 %
  - Aluminum: 60 %
  - Glass: 75 %
  - Plastic: 55 %
  - Wood: 30 %

- A binding landfill target to reduce landfill to maximum of 10% of municipal waste by 2035;
- Separate collection obligations are strengthened and extended to hazardous household waste (by end 2022), bio-waste (by end 2023), textiles (by end 2025).
- Minimum requirements are established for extended producer responsibility schemes to improve their governance and cost efficiency.

  Prevention objectives are significantly reinforced requiring Member States to take specific measures to tackle food waste and marine litter as a contribution to achieve EU commitments to the UN SDGs (Eurostat, 2016).

Kissling identified specific and generic success factors and barriers in the re-use of electrical and electronic equipment for a variety of different operating models in his research paper. The scope of the study is ICT and large household appliances. Success factors and barriers for re-use were identified through the conducting of semi-structured interviews with 28 case study partners representing the different models (Kissling et al, 2013). Another paper by Ongondo on reuse of WEEE but with the addition of successes and barriers to reuse is very useful for knowing what works and what fails and when you are developing/designing a system or standard it is just as important to know what works and what does not. Beyond resource efficiency, reuse of WEEE is an important waste prevention measure (Ongondo et al, 2013). The use of data previously unavailable and hard to source is becoming increasingly more available. Table 4 offers some indications as to the waste being reported from households and shows a steady picture. But the need is for the reporting of waste to increase so there is indication of it being processed.

United Kingdom					Million tonnes
	UK	England	Scotland	Wales	Northern Ireland
2010	27.1	22.1	2.8	1.3	0.8
2011	26.8	22.2	2.5	1.3	0.8
2012	26.5	22.0	2.4	1.3	0.8

Table 4: Waste from households, 2010 to 2012 (Defra, 2017)

Waste from Households, Table 4 is the agreed harmonised UK measure used to report household recycling to comply with the Waste Framework Directive (2008/98/EC) (Defra, 2017).

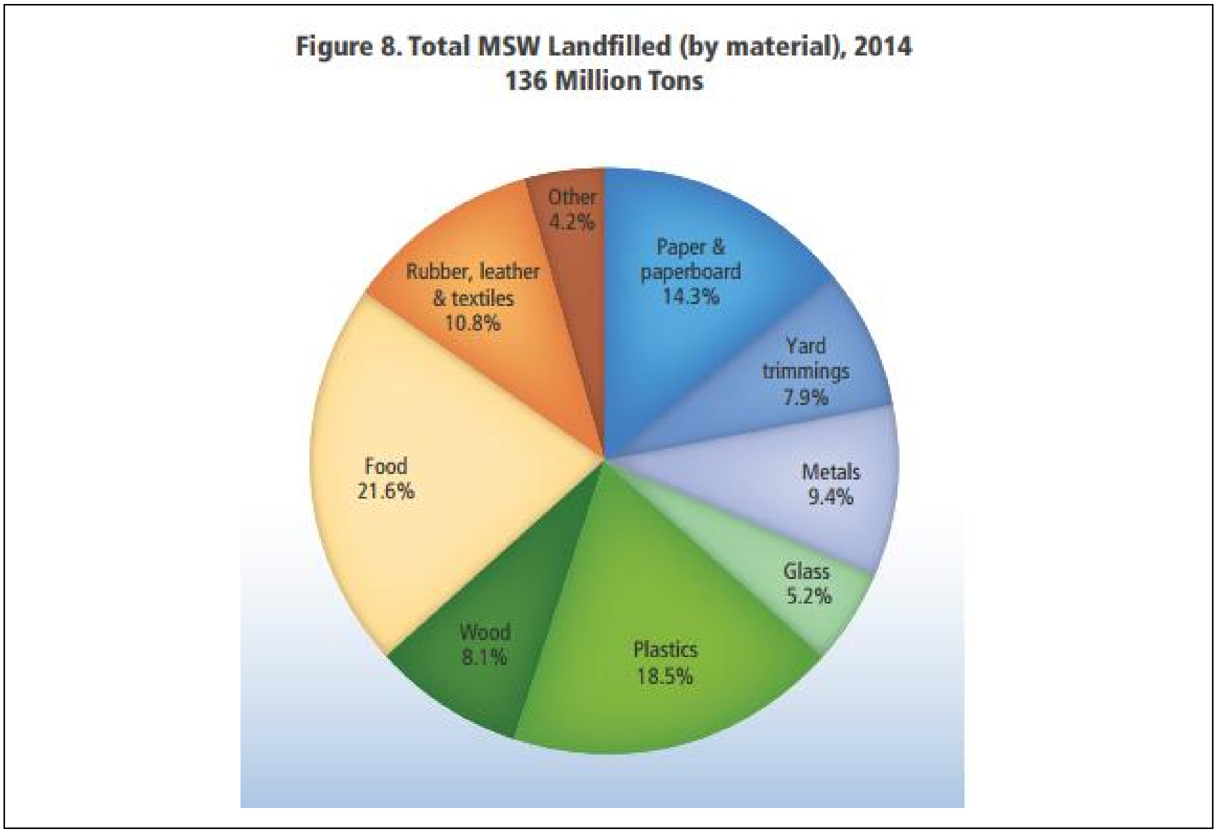


Figure 4.10: Material Solid Waste (MSW) in the US (MSW, 2016)

These percentages in Figure 4.10 represent MSW in the US and are highly typical of developed nations and probably worse in developing nations. It illustrates a problem that we are yet to get to grips with and certain sectors (food waste, plastics, paper) are creating even more problems for the environmental sustainability. The EU has made it a priority to work towards a Circular Economy where wastes are increasingly recognised as resources.

4.1.4 **Standards**

A Standard is a document that provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for purpose. Standards are established by consensus and approved by a recognized certification body, this allows for common and repeated use of their rules, guidelines or their results, aimed at the achieving optimum degree of order in a standardized way.

This research intends to inform or provide the background rationale for developing a standard/s on the Circular Economy. The importance of Standards is both related to their content, as well as the process it is for. Standards are intended to give world class specifications for systems, products and services. They aim to transform things with behaviours to match. Standards represent current "best practice" resulting from working group activities designed to fit the application it was intended for. But it is by no means perfect, and its quality and usefulness are affected by the participants. Most developed and some developing countries have their own National Standards. Using Standards alongside or in place of regulation, this could reduce the need for direct European Commission directives or regulations, thus offering stakeholder and recipients a route or system to develop better ways of working. There are also international standards bodies like ISO and IEC and European standards bodies CEN/CENELEC developing standards for a more systematic way of living. Comprehensive research published in June 2015 reported that standards contributed towards 28.4% of annual UK GDP growth between 1921 and 2013 and supported 37.4% of UK annual productivity growth between this period.

The International Society of Automation recently set up a survey to try to find out what the value of standards is to their members or to industry. The findings are in Figure 4.11 below.

Figure 4.11: The Importance of Standards to Industry (Wilkins, 2020)

Key findings from the survey included:

- 63% of respondents believe that industry standards will be extremely important in the future
- 87% of respondents believe that industry standards make processes and facilities safer
- 81% of respondents believe that industry standards help companies prove compliance to regulations
- 67% of respondents believe that industry standards make it easier to train and cross-train people in technical jobs
- 63% of respondents believe that industry standards make processes and facilities more cyber-secure (Wilkins, 2020).

This research cannot of itself produce a Standard because standards development requires certain stakeholders, has key stages and must have majority consensus before publication. However, this research will be an informative document to propose the way forward for circular economy standardisation.

Standards support market-based competition and help ensure the interoperability of complementary products and services. They reduce costs, improve safety and enhance competition. Due to their role in protecting health, safety, security and the environment, standards are important to the public (BSI, BEIS Annual Report, 2017).

There is growing recognition of the need to Standardize sub-national Ecological Footprint (EF) applications in order to increase comparability across studies and longitudinally. Methods and approaches for calculating the Ecological Footprint of municipalities, organizations and products are currently being aligned through a global Ecological Footprint standards initiative (Living Planet, 2012).

Standards are about standardizing products, services, and processes to ensure they work as intended. They potentially improve the quality of life by protecting people and the environment. Standards act as a powerful tool for strengthening international cooperation and supporting innovation. Standards generally play catchup to technology but can also advance technology, and when innovative clean-technology companies succeed, the economy and environment benefit.

Thousands of Standards are published every year by National, European and International Standards organisations, but they are written by a committee of experts from a range of relevant stakeholder groups. Stakeholder groups could come from individual subject experts, industry, government, academics, charities, or consumer groups. Standards are developed by consensus meaning that everyone in the working group must agree on the content being developed. Standards are voluntary, although some are used to underpin legislation and are generally seen as best practice.

In Europe anyone can submit a proposal for a Standard to be developed if they can explain why it is needed. The proposal is then submitted via the National Standards body of the submitter to the European Committee for Standardization (CEN) or CENELEC for electrotechnical Standards. Once enough CEN members give their consent and express an interest in being involved with the development work and the finance is available. Then CEN will assign the project to a Technical Committee (TC), who re-assigns the project to one of its Working Groups (WG). The CEN members appoint delegates to the TC to act as a bridge between the European and National standardization levels and to represent the national opinion. At the national level, mirror committees follow the standards progress and appoint experts to attend WG meetings to express their opinions. The WG draws up the actual text of the proposed standard as a working draft, see the stages of a European Standard.

The Stages of a European Standard:

*Standard proposal

*Working draft

*Draft standard (prEN) including public enquiry

*Final Draft

Finished Standard

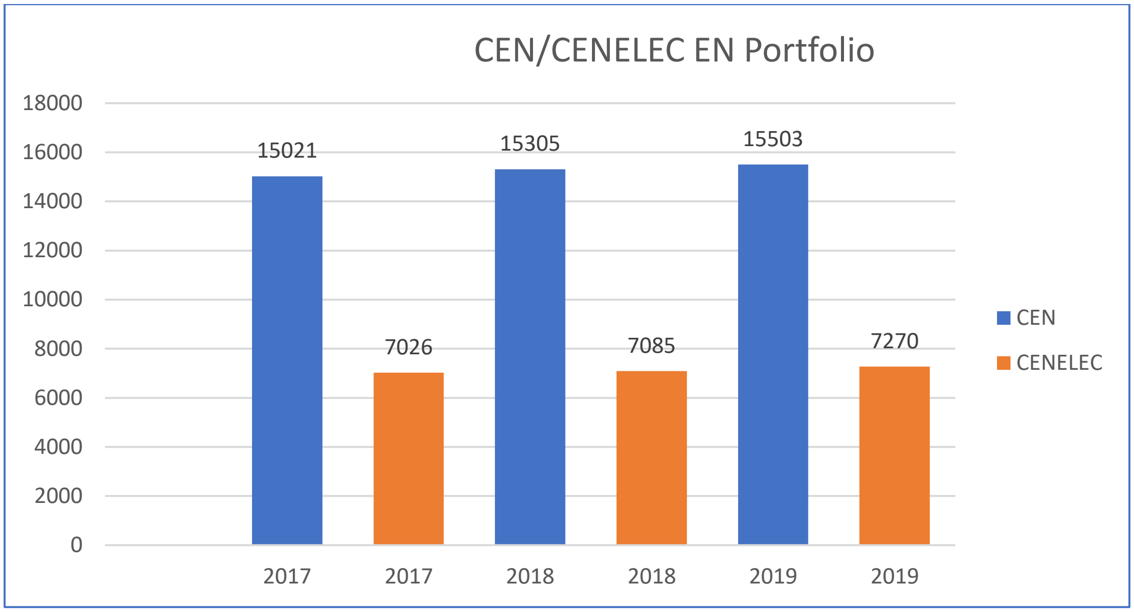


Figure 4.12: CEN/CENELEC Standards Portfolio (based on cencenelec statistics)

The above Figure 4.12 shows the large number of European Standards currently available from CEN and CENELEC but more importantly it shows how active both organisations have been over the years.

In Europe, there are three different categories of standards:

International Standards – these are standards developed or adopted by an international standards organisation (ISO or IEC), (e.g.- ISO 9001:2015 Quality Management Systems)

European Standards - these are standards developed or adopted by a European Standards Organisation (e.g.- CEN or CENELEC). CEN and CENELEC are the leading providers of voluntary European Standards and related products and services benefitting businesses, consumers and Standards users in Europe.

National Standards - these are standards developed or adopted by a National Standards Organisation – [e.g.- British Standards Institute (BSI), Canadian Standards Authority (CSA)].

International Standards make things work. They give world-class specifications for products, services and systems, to ensure quality, safety and efficiency. They are instrumental in facilitating international trade. ISO has published 22677 International

Standards and related documents, covering almost every industry, from technology, to food safety, to agriculture and healthcare. ISO International Standards impact everyone, everywhere (ISO, 2019).

The Stages of an International Standard:

*New Work Item Proposal (NWIP)

*Committee Draft (CD)

*Draft International Standard

*Final Draft International Standard

*Finished Standard

The main Standards developing organisations who would be interested in developing Standards for the Circular Economy would be:

National – Any National Standards body, e.g., British Standards Institute (BSI)

European – CEN/CENELEC

- The European Telecommunications Standards Institute (ETSI)

International – The International Standards Organisation (ISO)

- The International Electrotechnical Commission (IEC)
- American Society for Testing and Materials (ASTM)
- ISEAL Alliance – (ISEAL is the global membership organisation for credible sustainability Standards)

4.1.4.1 **Some Important Principles about Standardization**

Standards exist principally to provide a reliable basis on which common expectations can be shared regarding specific characteristics of a product, service or process (BSI, 2016).

- They represent good practices as defined by the participating experts
- Their content is achieved through consensus

- They are subject to unrestricted public consultation
- After publication they are subject to periodic review
- They are voluntary in application

4.1.4.2 **Why Develop a Standard?**

As previously mentioned, this research intends to inform or provide the background rationale for developing a standard/s on the Circular Economy. This research cannot of itself produce a standard because standards development requires certain stakeholders, has key stages and must have majority consensus before publication. However, this research will be an informative document to propose the way forward for circular economy standardisation.

Standards, whether international, European or national represent an increasingly significant dynamic in implementing environmental laws and policies.

Standardization is the activity of establishing agreed criteria that provide a reliable basis on which common expectations can be shared regarding specific characteristics of a product including a service or a process.

Standards are intended to give world class specifications for systems, products and services. They provide a skeleton for achieving economies, efficient solutions and interoperability that aid conventional trade and consumer purchasing confidence. They disseminate technical knowledge by making information readily accessible to all organisations. Most developed and some developing countries have their own national standards. Using standards alongside or in place of regulation could reduce the need for direct European Commission directives or regulations, thus offering stakeholder and recipients a route or system to develop better ways of working. There are also international standards bodies like ISO and IEC and European standards bodies CEN/CENELEC developing standards for a more systematic way of living. Comprehensive research published in June 2015 reported that standards contributed towards 28.4% of annual UK GDP growth between 1921 and 2013 and supported 37.4% of UK annual productivity growth between this period (Cebr, 2015).

Sector	% Utilisation
Health & Safety	80%
Quality Management	76%
Technical	65%
Environmental	63%
Codes of Practice	60%
Management	51%
Organisational Governance	35%

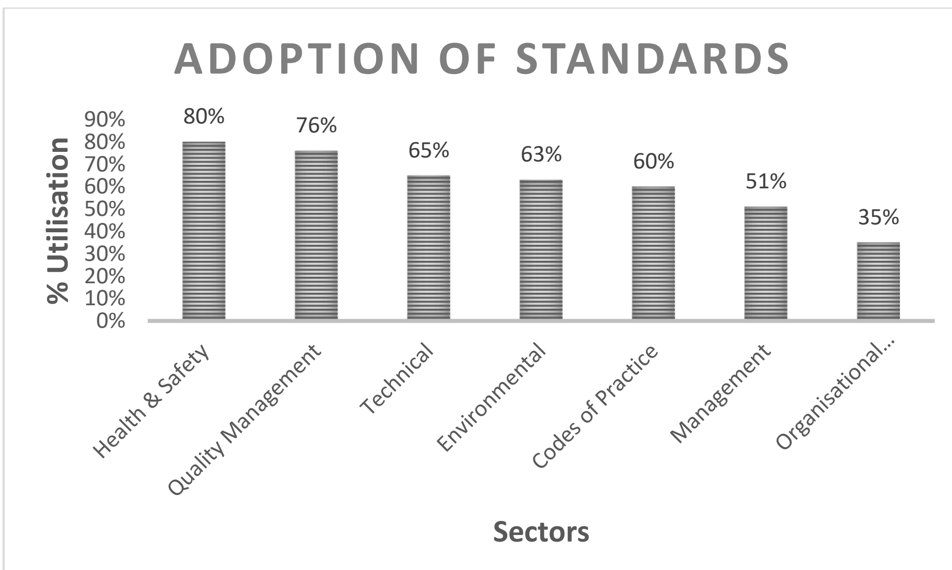


Figure 4.13: Adoption of Standards (Cebr Report, 2015)

The above spreadsheet and subsequently created bar chart Figure 4.13 represent the findings of an industry survey covering 527 companies within seven sectors across all UK businesses. Health and Safety standards are shown to be the most adopted with 80% usage. The survey highlights the possibility that a standard for the Circular Economy could be used by up to 63% of companies as it falls in the environmental category, but it would also cover some health and safety aspects like the control of harmful substances under REACH/RoHS, so could also come under the health and safety standards.

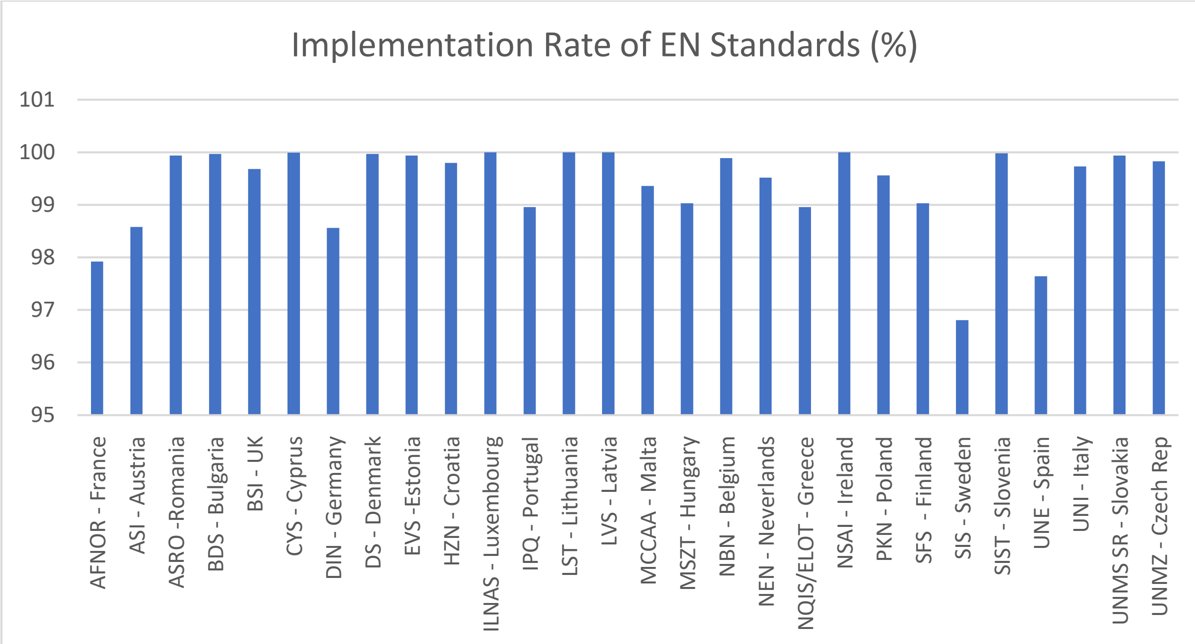


Figure 4.14: Implementation Rate of EN Standards (based on Cen/Cenelec statistics)

Standards have a high implementation rate in Europe as indicated and illustrated in Figure 4.14. However, there are not enough standards being developed in the Environmental arena. Environmental change is taking place so quickly that developing standards to meet this rapidly changing environment is not happening. Demand for the standards has outweighed the resources to develop them and so environmental politics has become more highlighted without the measures to tackle the problems.

This research cannot of itself produce a Standard because standards development requires certain stakeholders, has key stages and must have majority consensus before publication. However, this research will be an informative document to propose the way forward for circular economy standardisation.

4.1.4.3 **Standards Development**

The development of standards requires relevant and often highly detailed scientific and technical expertise to ensure that the standards being developed has consensus within the working group of the committee formed to develop that standard. Standards are developed and maintained by stakeholders who have a vested interest in the development of that standard. These stakeholders could be business and industry experts, consumers or consumer representatives, government representatives, researchers including universities, innovators, non-government organisations and others. The knowledge they bring to the table is carefully assembled and conforms to a process whether predetermined or typical. This can be extremely complex, especially within the European and International committees with different languages and different cultures. Standards developing committees often must deal with cross-cutting issues. Standards are universally developed in English and then translated in French, and other languages as the country using it requires. Whilst this is universally accepted it disgorges the added complexity of English words meaning different things to different people. Standards development ideally seeks to maximise the protection of both people and the planet.

The below diagram shows a typical standards development process. The emphasis here is on typical because the process must fit the intended outcome of the standard and the applicable complexity required to achieve this outcome might get overlooked within this process. All the standards developing bodies will have their own process with slight variations on what is in Figure 4.15 below.

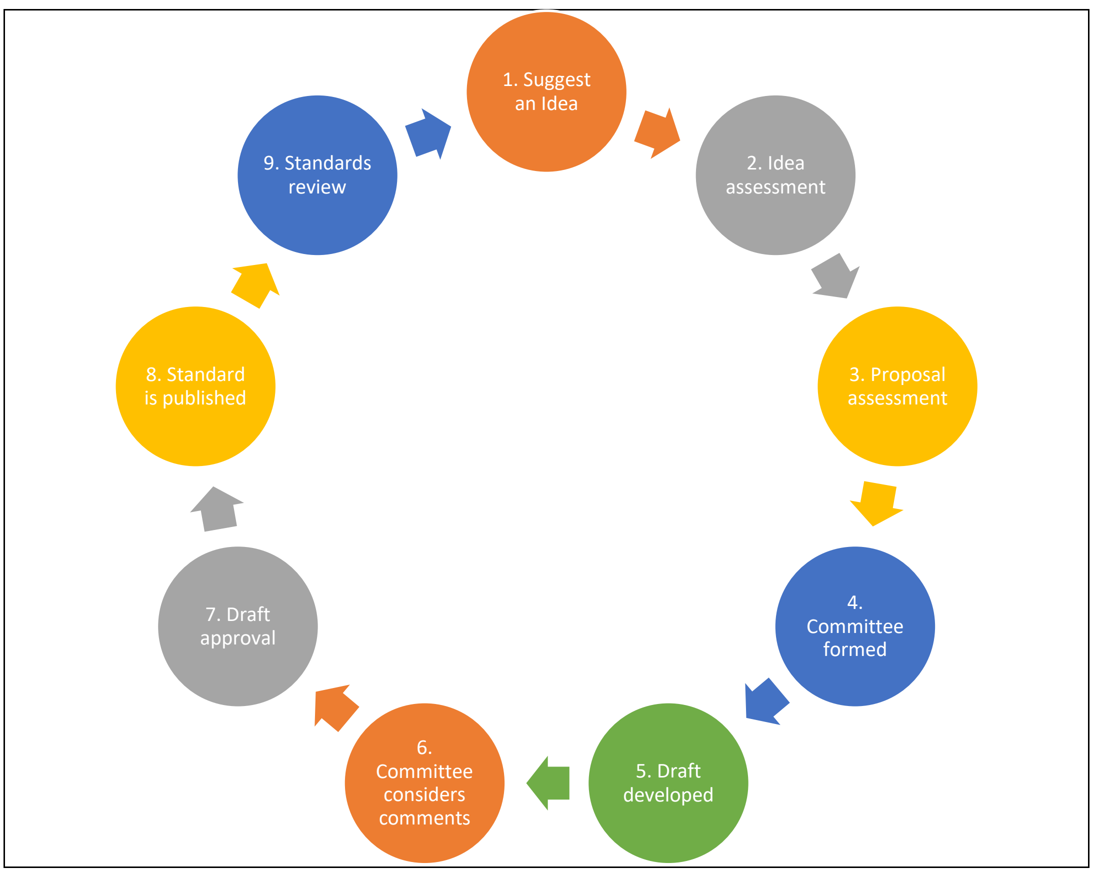


Figure 4.15: A typical Standards Development Process

(Redrawn: based on BSI diagram, How Standards are made, 2016)

1. Anyone can suggest an idea for a new standard (**a proposal for work**).
2. All ideas for new standards are assessed and stakeholders are consulted on the potential scope.
3. The proposal is assessed and if approved a stakeholder group is formed.
4. The stakeholder group forms a committee or drafting panel with standards body to draft the standard.
5. The draft is then issued for public consultation.
6. The committee or drafting panel considers the comments and prepares an updated draft (this stage can be repeated).
7. The draft goes through a final approval process.
8. Once the standard passes final approval it is published.
9. Standards are reviewed every five years, some as early as two years from publication. The committee or drafting panel considers any comments they have received about the standard and decides whether it needs to be withdrawn, confirmed or reconfirmed, amended or revised. A decision to amend or revise the standard will lead to a new **proposal for work**. (Based on Figure 4.15)

4.1.4.4 **The Benefits of Standards**

- They increase the safety of products.
- Serve as a basis for improving the quality of products or services.
- They ensure strong characteristics of products, processes and services.
- They ensure that products are fit for purpose.
- They serve as a basis for conformity assessments.
- They lead to better efficiency in the use of associated resources.
- They support the process of preparation and implementation of technical regulations.
- They increase manufacturers competitive edge.
- They contribute to removing the barriers to trade.

- They contribute to the protection of the environment and the maintenance of an ecological balance.
- They reflect current scientific research and innovation.
- They contribute to mutual understanding between affected parties.

(BSI, BEIS Annual Report, 2017)

It is clear for everyone to see that humanity currently consumes more natural resources than it can replenish, and the alarming rate of this occurrence is why the Circular Economy has become such a global necessity. In the last forty-five years, demand for natural resources on the planet has doubled due to the high standard of living in the developed and the developing nations and the increase in the world's population. Today humanity uses 50% of the planet's fresh water, in forty years' time this is predicted to rise to 80% (Alcoforado, 2015).

4.1.5 **Increasing Interest in the Circular Economy**

There is no doubt that interest in the Circular Economy throughout Europe and across the world is growing year on year. This is partly because we are not acting fast enough to transition to a Circular Economy.

The Circular Economy is gaining increasing attention in Europe and around the world as a potential way for our society to increase prosperity, while reducing dependence on primary materials and energy. The growing importance of the concept of the Circular Economy to attain sustainable development has encouraged scholars to propose different ways to understand it. Prieto-Sandoval's study carried out a systematic literature review that resulted in three main outputs: a knowledge map of the Circular Economy, an analysis of the main notions of the concept, principles and determinants of a Circular Economy (Prieto-Sandoval et al, 2017).

In the last few years, the Circular Economy has been receiving increasing attention worldwide 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 (Ghisellini et al, 2015). The increased attention in the Circular Economy concept is due, in part, to its capacity to provide the basis for reconciling the problem of how to promote productivity while considering the externalities of the production process, the consumption of products and the end-of-life impacts (Sauve et al, 2015).

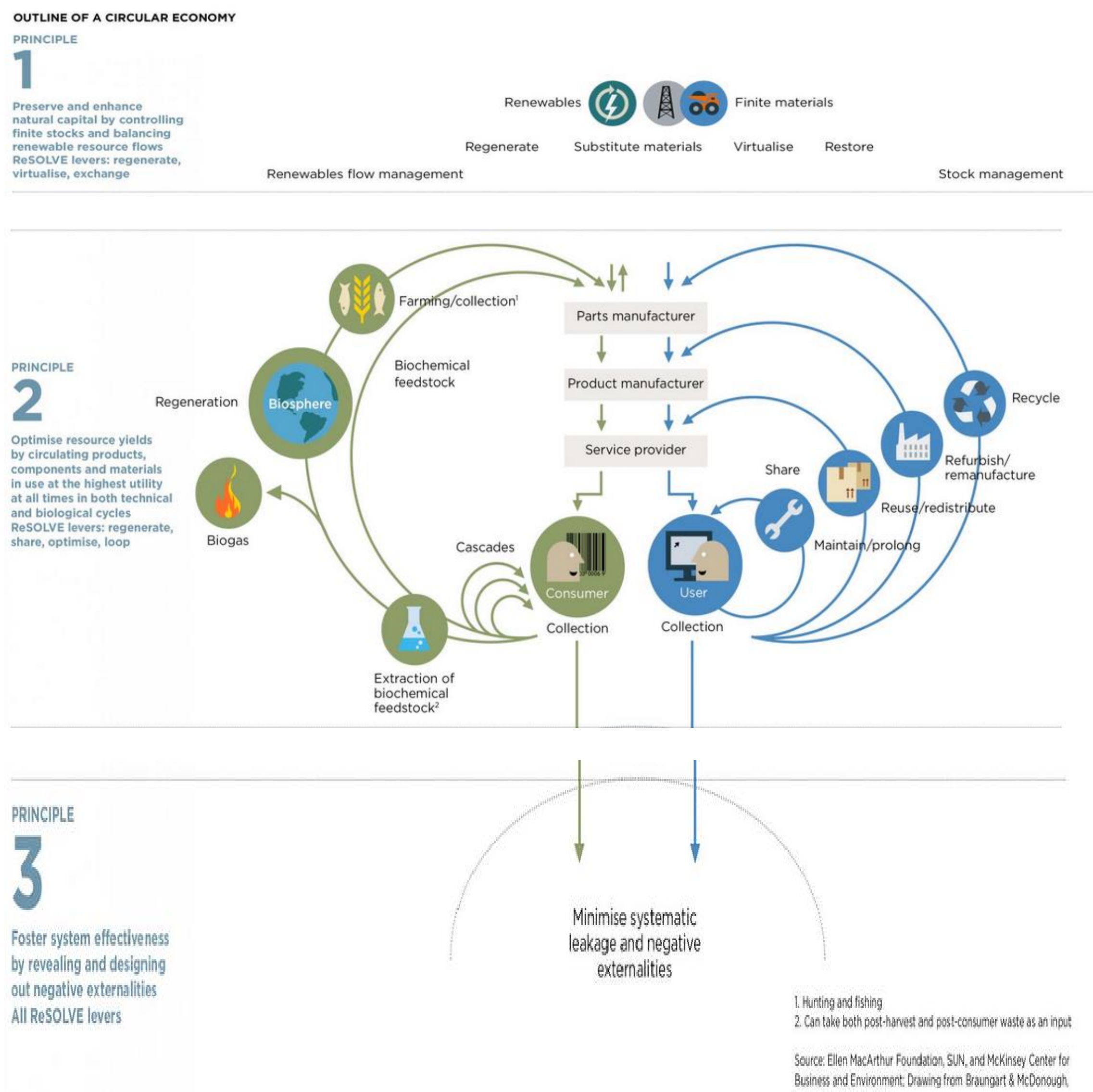


Figure 4.16: Outline of a Circular Economy (EMF1, 2015)

Table 5 highlights the most relevant process parameters compatible with circular thinking. Environmental effectiveness cannot be evaluated without further investigation.

Linear system mechanisms	**Circular system mechanisms**
Business perspective	
Product as value creation source Profit margins are based on the difference between the market price of a product and the production cost. The strategy for increasing profits is to sell more products and keep production costs as low as possible. Technological innovation makes old products obsolete and urges consumers to buy new products. Protection of intellectual property rights, a main source of value, leads to protective design measures, such as creating barriers to repairing a product, rather than sharing product technical information and repair manuals.	*Functionality/performance as a source of value creation* Products are part of an integrated business model focusing on the delivery of a performance or functional service. Competition is mainly based on the creation of added service value of a product, not solely on its sales value. Social/ business model innovation allows the creation of extra value by applying technological innovation to solving societal needs. As products are part of a company's assets, cost minimisation drives product longevity, reuse, reparability and remanufacturing.
Economies of scale in global production chains Cost efficiency drives the optimisation of global production chains, minimising the costs of resources, labour and transport.	*Location of production and use tend to be more linked* As the provision of a service is physically linked to the location of the customer, there is an incentive to produce/manage physical products used in a service close to the user.
Steer consumer needs towards product offer Products with short lifespans are preferred as they are cheaper to make and support a market for new products that replace old ones. Maintenance and repair are avoided, as it is more profitable to sell new products than to repair old ones.	*User needs/wants drive the role of a product* Offering the best service means matching the (intangible) needs of the user with a combination of services and products.

Tendency to disregard end-of-life phase There is no economic incentive for product life extension, reuse or remanufacturing as they counteract most linear business models.	*Internal incentive to incorporate end-of-life phase in business model* As products are assets, minimising life-cycle costs is an implicit incentive for a company, inducing a search for the best economic equilibrium between reusing, repairing, remanufacturing and recycling products.
Consumer perspective	
Consumerism follows marketing Consumers want new products that keep pace with fashion and technological advances. Consumers must match their needs with the product offerings available.	*Customer satisfaction is an important driver* In a service relationship with a company, the customer experience feeds back more strongly to the service provider, raising consumers' awareness of their actual needs. In other cases consumers become prosumers who co-create or co-produce the products and services they need.
International opportunities for cost reduction Consumers seek the cheapest version of a product on international markets, enabled by e-commerce.	*Local-first attitude* Accessibility to the service provider is part of the service experience, which leads to proximity as a customer choice criterion.
Ownership is the norm Owning a product is regarded as the normal way to fulfil needs. Over time, previously luxury products become commodity goods due to decreasing production costs. Beyond legal warranty, product repair is considered too expensive compared with buying a new product. Do-it-yourself repair is considered too difficult due to complex and protective product design.	*Accessibility is the norm* Fulfilling needs is driven first and foremost by accessibility of a product and the satisfaction provided by its use. Different consumer segments can access products of their choice through customised services or by sharing products, for instance in peer-to-peer networks. Service agreements provide an incentive for product care for the producer and the user, depending on the agreement.

Linear system mechanisms	Circular system mechanisms
Low/no residual value of products *End-of-life products (broken or obsolete) are considered a burden, to be disposed of as cheaply as possible — by selling on the second-hand market, storing at home, or through regulated waste disposal systems or illegal incineration or dumping.*	*End-of-use incentives incorporated* *If products are part of a service, there are incentives to return them to the provider after use, avoiding stocks of obsolete products in households, or illegal dumping.*
Policy perspective	
Dependence on existing production system There is a strong link between mass production of goods, and the focus on cutting costs in general, and making the production as efficient as possible, often resulting in lower labour costs and less job creation.	*More focus on facilitating skilled workforce* More localised and service-based activities require a skilled but affordable workforce. Policymakers can facilitate this by shifting taxes from labour to resources.
Global playing field Competition for economic factors on the international market steers national social and environmental policies.	*Less risk for outsourcing jobs* As management of products as local assets is less likely to be outsourced, there is less incentive for a race-to-the-bottom in social and environmental policies.
Balance consumer protection with economic stakes Protection of consumer safety and health is mostly reactive and geared towards protecting existing economic stakes, such as value-added tax (VAT) income.	*Facilitate safe and healthy services with regulation* As safety and consumer health are business incentives for high-quality performance, policies focus on facilitation of these types of services.
(*Action prompted by health or environmental concerns* There is no inherent incentive for regulation of the waste phase of products. Only when	(*Facilitation of end-of-life management* Extended producer responsibility rules create incentives for companies to internalise end-of-life management. Governments provide basic

waste-related health or environmental concerns arise is regulatory action taken to minimise negative impacts.	infrastructure and fiscal measures supporting reverse logistics.

Table 5: Key mechanisms shaping the role of products in a Linear and a Circular Economy

(Modelled on EEA Report/NO 6/2017)

4.1.6 **Transition Towards a Circular Economy**

The transition towards a circular economy cannot be done in isolation, it requires collaboration, value chains, networks and systems thinking to build trust and transparency to work together. Transition takes on many criteria some which will be highlighted in this report, economies around the world are moving at different speeds with different approaches but most recognise that the need to change is greater than it has ever been and is getting worse. Transitioning towards a CE requires systemic change and systems thinking.

4.1.6.1 **The 7th EAP Priority Objectives**

Environment Action Programme (EAP) – DECISION No 1386/2013/EU General Union Environment Action Programme to 2020 "Living well, within the limits of our planet". The EU has consistently guided environmental policy in Europe by defining priority objectives to be achieved over several years. This seventh EAP of its kind follows this trend. The EU has seen the need to increase its efforts to protect the EU's natural capital, stimulate resource efficiency, low carbon growth and innovation and protect the health and well-being of its citizens. The EAP provides member states with a common objective in achieving the priorities of the programme and an opportunity to share in its application. This decision has been written into Legislation in the Official Journal (OJ), it stipulates in Article 3.2 that public authorities at all levels shall work with businesses and social partners, civil society and individual citizens in implementing the 7th EAP. Not many European citizens are aware of this obligation. Article 4 also has a strong obligatory presence; it says The Commission shall ensure that the implementation of the relevant elements of the 7th EAP is monitored in the context of the regular monitoring process of the

Europe 2020 Strategy. This process shall be informed by the EEA's indicators on the state of the environment as well as indicators used to monitor progress in achieving existing environment and climate-related legislation and targets such as climate and energy targets, biodiversity targets and resource efficiency milestones referenced in DECISION No 1386/2013/EU,2013.

The European Circular Economy Stakeholder Platform is a joint initiative by the European Commission and the European Economic and Social Committee. Most of the larger European governments have developed strategies based on the Circular Economy. This includes countries like – The Netherlands, France, United Kingdom, Spain, Greece, Finland, Slovenia, Luxembourg, Belgium, Portugal, Germany, and Italy.

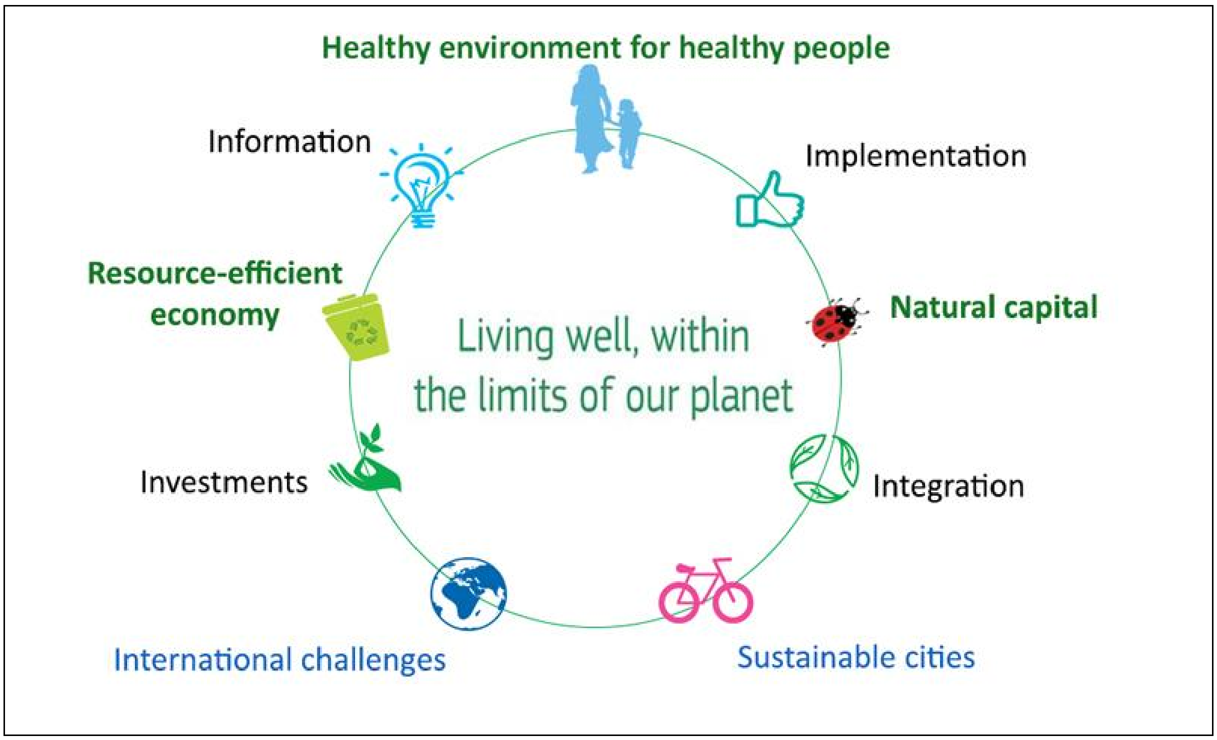


Figure 4.17: The 7th EAP Priority Objectives (EC, 2019)

No	Priorities	Description
1	Natural capital: “Nurturing the hand that feeds us”	This refers to the biodiversity that provides goods and services we rely on, from fertile soil and productive land and seas to fresh water and clean air to breathe.
2	Resource efficient economy: “Doing more with less”	With rising natural resource prices, scarcity and dependency on imports, Europe’s competitiveness will depend on improving resource efficiency across the economy.
3	A healthy environment for healthy people: “taking care of the environment is taking care of ourselves”	Challenges to human health and wellbeing, such as air and water pollution, excessive noise, and harmful chemicals. It is crucial that Europe is resilient to challenges posed by new and emerging risks, including the impacts of climate change.

The EAP programme includes an “enabling framework”, with the next four priorities aimed at;

Improved implementation
Increased information
Secured investments
Better integration

No	Enabling Priorities	Description
4	Improved implementation: “Good for the environment, our health and our wallets”	Full implementation of EU waste legislation would: save €72 billion a year Increase the annual turnover of the EU waste management and recycling sector by €42 billion and

		could create over 400,000 new jobs by 2020.
5	Increased information: “Best decisions based on latest data”	The EAP aims to: Improve the way data and other information is collected, managed and used across the EU; Invest in research to fill knowledge gaps; And develop a more systematic approach to new and emerging risks.
6	Secured investments: “Green incentives mean green innovations”	This can only happen if impacts on the environment are properly accounted for and if market signals also reflect the true costs to the environment. This involves applying the polluter-pays principle; phasing out environmentally harmful subsidies; shifting taxation from labour towards pollution; and expanding markets for environmental goods and services.
7	Better integration: “Tackling multiple challenges with one approach”	A better-defined integration of environmental concerns into other policy areas like regional policy, agriculture, fisheries, energy and transport will guarantee better decision making and coherent policy approaches that deliver multiple benefits.

Two more priorities complete the EAP;

No	Priorities	Description
8	Sustainable cities: “Working together for a common solution”	Densely populated cities often share common problems such as poor air quality, high levels of noise, greenhouse gas emissions, water scarcity and the inevitable waste. The EAP aims to help cities become more sustainable.
9	Tackling international challenges: “Living well, within the limits of our planet - is a global aim”	The EU and its member states are committed to: engaging more effectively in working with international partners towards the adoption of sustainable development goals and further steps to reduce the impacts on the environment beyond EU borders.

(Based on European Commission, 2019)

The Action Plan identified five priority sectors to speed up the transition along their value chain. These are plastics, food waste, critical raw materials, construction and demolition, biomass and bio-based materials (Europa.eu, 2018). This document will only cover critical raw materials because of the context in which this thesis is rooted.
There is a need for metrics to analyse complex business models in the circular economy. LCA currently is the best-defined system to analyse the environmental aspects, and is capable to analyse circular systems, product service systems and systems for recycling. Since new sustainable business models are part of the transition towards a circular economy, there is a need for a combined analysis of value and eco-burden. The circular transition framework reveals pitfalls and opportunities in implementation.

The quest for a sustainable society is the quest for solutions in a Circular Economy. The notion that materials in the techno sphere must be recycled, toxic emissions must be eradicated, fossil-based energy must be replaced by renewable energy and that materials from the biosphere provide new opportunities for innovations, is not new. New, is however, the focus on the transition from the old, linear and unsustainable systems towards new circular systems. Essential for such a transition is that new business models must be developed to support this transition. These business models must have extra added value in comparison to the market competition, combined with lower eco-burden through less resource depletion as well as less environmental pollution (Scheepens et al., 2015). Scheepens presents the transitioning from the old (for some current) linear and unsustainable model to the new circular economy model. These newer models must have added value built in to achieve the sustainable development goals being brandished. So, this paper applies the LCA-based Eco-costs Value Ratio model to analyse the potential negative environmental effects on businesses introducing the CE model. The circular transition framework reveals pitfalls and opportunities in implementation, like the coordination between business models and aligned governmental policies. Having a system of showing added value to the Circular Economy can only be positive for the development of a standard/s on the Circular Economy. The Circular Economy concept can be quite expansive as illustrated in Figure 4.18 (below). Some of these areas are mentioned in later sections of Chapter 4, ecology and atmospheric science (climate resilience).

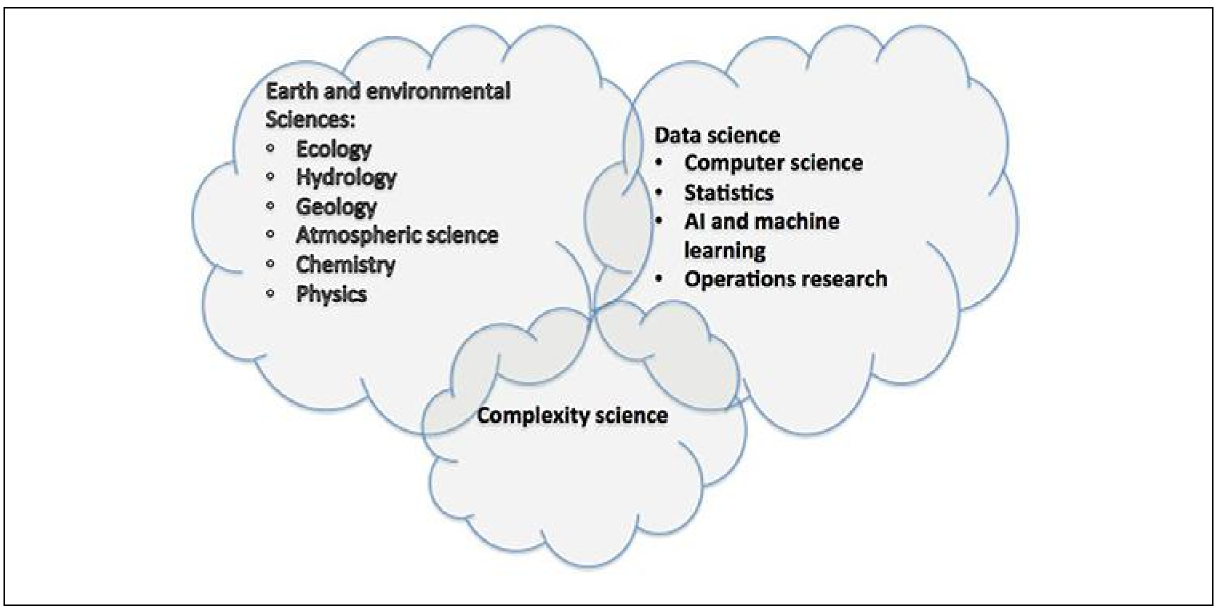


Figure 4.18: The Cross-disciplinary nature of Environmental Data Science (Blair et al, 2019)

The European Commission created a European Circular Economy Stakeholder Platform as a virtual open space aimed at promoting Europe's transition to a circular economy by facilitating policy dialogue among stakeholders and by disseminating activities, information and good practices on the "Circular Economy".

Circular Economy systems keep the added value in products for as long as possible and eliminate waste. They keep resources within the economy when a product has reached the end of its life, so that they can be productively used again and again and thus create further value. Transition towards a more Circular Economy requires changes throughout the value chains, from product design to new business and market models, from new ways of turning waste into a resource to new models of consumer behaviour. This implies full systemic change and innovation not only in technologies, but also in organisation, society, finance methods and policies. A 'Circular Economy' is an approach that would transform the function of resources in the economy. Waste from factories would become a valuable input to another process-and products could be repaired, reused or upgraded instead of thrown away. Resource consumption targets that reflect environmental constraints should be considered at a global level. Coordination of national policies would help create a level playing field across major markets, easing competitiveness concerns and reducing the costs of implementation (Preston, 2012).

The circular economy is seen here as a model for industrial organisations that will help developing countries to industrialise and developed countries to increase wellbeing and reduce vulnerability to resource price shocks but without placing unsustainable pressure on natural resources and negatively impacting the environment. Preston explores the concepts of the Circular Economy, its key components, challenges and opportunities and the importance of international cooperation.

4.1.6.2 **Key Deliverables since the adoption of the Circular Economy Action Plan**

The Circular Economy Action Plan seeks to increase the circularity of the EU economy by preserving its natural environment and supporting the contribution European industry will make to achieving a climate-neutral continent. The key deliverables identified by the plan are listed below:

A legislative proposal on online sales of goods (Dec 2015)
A legislative proposal on fertilisers (Mar 2016)
The launch of the innovation deals (May 2016)
Innovative eco-design (Nov 2016)
Significant reduction in food waste (All 2016)
A waste to energy programme (Jan 2017)
A proposal to amend the RoHS Directive (Jan 2017)
The platform to support the financing of the Circular Economy (Jan 2017)

Three years after the adoption of the first circular economy action plan all 54 actions have been delivered and a new action plan is being worked on.

4.1.7 **European reaction to the Circular Economy**

4.1.7.1 **The European Commission**

The European Commission is the EU's executive organisation who takes decisions and legislate on the Union's political and strategic direction. The Commission is led by a President who is elected by the European Council – made up of the European Union's heads of State for a term of five years. The Commission helps shape the EU's overall strategy, proposes new EU laws and policies, monitors their implementation and manages the European Union's budget. The Commission is then divided into departments that are tasked to develop policies for specific areas.

The official position of the European Commission on the Circular Economy was presented on December 17, 2012, under the name of a "Manifesto for a Resource- Efficient Europe". This document emphasized from the first paragraph that: In a world with growing pressures on resources and the environment, the EU has no choice but to go for the transition to a resource-efficient and ultimately regenerative Circular Economy (Bonciu, 2014).

It was December 2014 when the European Commission decided to withdraw its legislative proposal on waste, with a commitment to use its new horizontal working methods to present a new package by the end of 2015. The new package would cover the full economic cycle, not just the reduction of waste targets and would draw on all the resources of the Commissions services. The conversion towards a Circular Economy represents both a commitment to the "2030 Agenda for Sustainable Development" and the opportunity to alter the EU member economies closer to the Commissions priorities such as employment, economic growth, climate conservation and energy efficiency.

The European Commission adopted its updated action plan in 2015 to accelerate Europe's transition towards a Circular Economy, boost global competitiveness, promote sustainable economic growth and generate new jobs. The EU's Circular Economy action plan provides a future oriented agenda for achieving a cleaner and more competitive Europe in collaboration with economic actors, European citizens, civil society organisations and consumers.

4.1.7.2 **Key Areas of the Circular Economy Package:**

1. Resource Efficiency – using resources more efficiently for a greener, more competitive economy.
2. Raw Materials – ensuring our use of raw materials does not deplete the planet's resources.
3. Consumption – providing transparent information to consumers enabling them to make greener choices.
4. Eco-innovation – enabling green growth and the transition towards a more Circular Economy.
5. Production – promoting greener products and supporting greener companies and organisations.
6. Waste prevention and management – reducing waste and improving waste management.

The European Commission adopted its updated action plan to accelerate Europe's transition towards a Circular Economy, boost global competitiveness, promote sustainable economic growth and generate new jobs. Included in the action plan is four legislative proposals to amend these legal acts:

Waste Framework Directive

Landfill Directive

Packaging Directive

Directives on end-of-life vehicles, batteries and accumulators and waste electrical and electronic equipment.

The European Commission's action plan seeks to apply the Circular Economy in each step of the value chain, from production to consumption, repair and re-engineering, waste management and reuse of raw materials. The Circular Economy is the Commission's unique attempt to develop a sustainable economy for Europe that acts as part of a broader strategy that impacts all policy domains.

The European Circular Economy Stakeholder Platform is a joint initiative by the European Commission and the European Economic and Social Committee. Most of the larger European governments have developed strategies based on the Circular Economy. This includes countries like – The Netherlands, France, United Kingdom, Spain, Greece, Finland, Slovenia, Luxembourg, Belgium, Portugal, Germany, and Italy.

4.1.8 **Member States**

The European Union consists of 27 countries politically and economically unified and geographically located in Europe. These 27 countries are Austria, Belgium, Bulgaria, Czechia, Croatia, Cyprus, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxemburg, Malta, the Netherlands, Poland, Portugal, Romania, Slovenia, Slovakia, Spain, and Sweden

This section will only cover five member states as a sample of reaction to the Circular Economy in Europe.

4.1.8.1 **Germany and the Circular Economy**

In Germany, an early form of the Circular Economy emerged in the 1970's with the Waste Disposal Act, which then became the Closed Substance Cycle Waste Management Act of May 2000. The purpose of the act was to promote closed substance cycle waste management, in order to conserve natural resources and to ensure environmentally compatible disposal of waste.

The waste management policy in Germany over the past 20 years is based on closed cycles and assigns disposal responsibilities to manufacturers and distributors of products. This has made the Germans even more aware of the necessity to separate waste, led to the introduction of new disposal technologies and increased recycling capacities (Nelles et al, 2016). This is typical of the Linear Economy Model, but Germany have realised that waste is a useful source of energy and raw materials and so have been collecting metals, glass and textiles and recycling them for new uses.

Now, 14% of the raw materials used by the German industry are recovered waste, thus leads to a reduction of the extraction levels and of the related environmental impacts. Germany's modern closed cycle management contributes approximately 20% to achieving the German Kyoto targets on the reduction of climate relevant emissions (Nelles et al, 2016).

Germany has a good record on recovery of packaging materials. Common packaging materials are glass, aluminium, tin plate, plastic, paper, cardboard and wood, all valuable secondary raw materials which if recycled and reused will contribute to reducing the exploitation of natural resources, lead to energy savings and ultimately the reduction of harmful greenhouse gases.

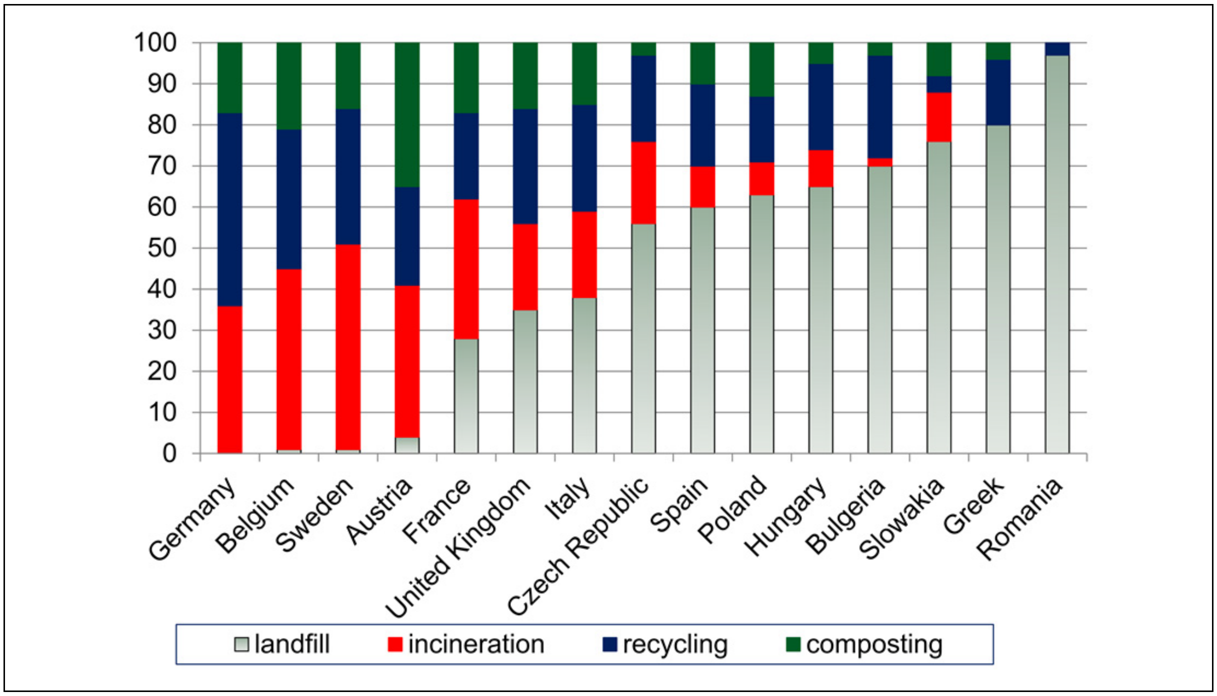


Figure 4.19: Municipal Solid Waste treatment in selected EU countries (in %)

(Source – Eurostat, 2016)

Municipal waste is mainly produced by households and includes similar wastes from commercial enterprises, offices and public institutions. The German government has gone a step further and announced plans to stop using coal as an energy source by 2038. This move is not just a move away from using coal but more importantly an entry into renewable energy based on Circular Economy principles and will cut a quarter of all CO2 emissions in Germany.

4.1.8.2 **The Netherlands and the Circular Economy**

In many sectors the Dutch economy is already on the way to becoming a Circular Economy and can primarily be classed as a reuse economy; the amount of waste is falling as the economy grows and waste is being used in an ever-increasing degree.

The necessity to strive for a Circular Economy in the Netherlands comes from a concurrence of three developments:

1. Explosive demand for raw materials – the earth's population is using 34 times more materials, 27 times more minerals, 12 times more fossil fuels and 3.6 times more biomass. The demand for raw materials will further increase as a result of global

population growth, the rapidly growing middle class in emerging economies and the application of new technologies that require specific raw materials. This growth is not sustainable.

2. Dependency on other countries – the Netherlands and Europe are dependent on other countries for raw materials. The Netherlands imports 68% of its raw materials from abroad.
3. Interconnectivity with climate (CO_2) emissions – the extraction and use of raw materials has a negative effect not only on the environment and natural capital. It also makes a considerable contribution to the consumption of energy and the emission of CO_2.

The transition to the Circular Economy through the eyes of the Dutch are seen through three strategic goals that have been formulated by their government wide programme:

1. Raw materials in existing supply chains are utilised in a high-quality manner.

2. In cases in which new raw materials are needed, fossil-based, critical and non-sustainably produced raw materials are replaced by sustainably produced renewable and generally available raw materials.

3. They develop new production methods, design new products and organise areas differently. They will also promote new ways of consumption.

The Dutch economy scores highly in terms of materials efficiency, and the use of materials, while still high is diminishing. Things are slightly different when it comes to consumption. The Dutch consume a lot of imported goods with relatively large ecological footprint (EC, 2015).

However, if there is only one country that should be able to embrace the Circular Economy, it is The Netherlands. They have the geographical position; they are already production efficient and have the level of prosperity that facilitates a more efficient use of materials as opposed to more product consumption (Ministry of Infrastructure and the Environment, 2016).

4.1.8.3 **Romania and the Circular Economy**

Romania, an Eastern European economy integrated in 2007 into the EU, was ill-prepared for EC transition. According to Eurostat statistics, Romania's economy is among the three economies (alongside Malta and Estonia) where economic growth has not been decoupled from pressure on the environment and natural resources, the Romanian economy is mainly dependant on production and manufacturing, economic activities requiring natural resources and adversely affecting the environment through pollution. Further, from the perspective of fundamental macroeconomic indicators regarding efficient use of resources, Romania is the most vulnerable EU Member State on the transition to the Circular Economy. In addition to that, certain traditional EU member states who honoured their legal obligations under the 2015 Circular Economy package, claim that Romania has an unfair economical competitive advantage. Finally, the multi-level governance system required by the Circular Economy, "top-down" and "bottom-up", is almost unfunctional in Romania, especially at regional level, and the influence of the private economic sector exists only at the lower levels of government. From the business environment perspective, there are currently no examples of economic agglomerations in Romania where the Circular Economy best practices have been implemented nor a proper organizational culture prepared to adopt those principles (Botezat, et al, 2018).

Botezat's research sheds a different light on a country's transition to the Circular Economy, one that is uncommon among reports/articles, it does not paint an all so rosy picture. This is welcome and a good breeding ground for a wholistic implementation of Circular Economy concepts, models and practices in Romania. The limitations of the classic linear economic system have generated the emergence of new contemporary economic models, most often of hybrid type, which have significantly contributed to the conversion of classical production and consumption relations. The main objective in this research report is the identification of developments of the Circular Economy in Romania under the new sustainability paradigm using econometric models.

By applying the principles of the Circular Economy in Romania, high energy efficiency and energy savings can be achieved, attracting and reusing waste within the technological processes, creating new durable jobs and opportunities to integrate and capitalise long-term potential and to create indivisible and permanent connections between sustainability and the economic well-being of the population (Dragoi, 2018). This research conducted by Dragoi, describes the achievements of the objectives of the Circular Economy entails an in-depth understanding of the mechanisms and determinants of functioning of the economy entirely. However, in order to achieve these objectives specific indicators were used, for which data sets were available for ten years or more which were necessary to describe and understand several specific transformations and evolutions that may be circumscribed to the concept of the Circular Economy.

4.1.8.4 **Finland and the Circular Economy**

Finland has set themselves the formidable target of becoming a world leader in the Circular Economy by 2025. The target is based on opportunities arising from global trends and challenges, such as urbanisation, climate awareness, population growth and gentrification. They are using the cornerstone of environmental sustainability as the foundation for achieving their target, this is:

- *Economy* - The Circular Economy will be a new cornerstone for the Finnish economy
- *Environment* – Finland as a model country for the challenge of scarcity
- *Society* – From adaptor to pioneer

Digitisation will be a key enabler in their transport focussed area as passenger transport moves towards smart, easy-to-use transport that is based on sharing and services like Mobility as a Service (MaaS) – and subsequently much more resource efficiency (Sitra 121, 2016). Finland promotes themselves as having a strong technological base that strongly supports transitioning to a Circular Economy. They have a high level of expertise in the technology sector with regard to energy efficiency, digitalisation, internet of things and design. They have a growing number of technology companies, which create enabling solutions to advance technology in the Circular Economy (Sitra 121, 2016).

4.1.8.5 **United Kingdom and the Circular Economy**

The UK like many other EU countries has rooted its commitment to the Circular Economy based on the EU Circular Economy package. However, the UK having left the EU their policy will be determined independently of Europe's but will undoubtedly include most of the main ingredients. Brexit was the withdrawal of the United Kingdom from the European Union. Around 80% of the environmental laws currently in force in the UK were created in Europe, including the European targets on waste recycling and carbon emission reductions. The UK government has affirmed that the environment will not be worse off after Brexit, arguing that it might even be beneficial in creating opportunities for innovation in the Circular Economy. There has been a widespread adoption of EU laws and amendments to transpose them into UK law. The relevant Statutory Instrument enabling the creation of a framework for the majority of New Legislative Framework regulations was formally adopted in the House of Commons on 20 March and entered into force on the effective date of Brexit.

This is significant for the continuation of UK input into the development of Standards for the Circular Economy and this thesis.

4.1.8.6 **Examples of some European Circular Economy Initiatives**

Zero Waste Europe

Zero Waste Europe work on a wide range of projects and policy areas with the single objective of advancing the zero-waste future for Europe. Their mission and vision is to empower communities and change agents from around Europe to redesign their relationship with resources, to adopt smarter lifestyles and sustainable consumption patterns in line with Circular Economy resource management (Zero Waste Europe, 2020).

SINCERE – Sino-European Circular Economy and Resource Efficiency

This project is part of a collaborative funding initiative involving research institutions from the member states of France, Germany, United Kingdom and The Netherlands. It also includes China.

This project will develop new economic modelling tools to understand the resource use patterns of China and the EU. The project will also address indicators and metrics, institutions and policies and will examine historical patterns between resource indicators, trade and macro-economic performance, with the overall aim of strengthening collaboration between European and Chinese researchers. One of the research areas is WP 5 – Resource Efficiency, Circular Economy and Macroeconomics; WP 5 will develop quantified model-based scenarios and storylines to explore possible futures for both regions (SINCERE, 2019).

4.1.9 **Legislation**

Regulatory Compliance is complex at the best of times and most organisations shy away from it but know it is a must have if they want to sell products. It requires a deep knowledge of the regulations and knowledge of the requirements of the country you are selling into. It is a juggling act to avoid expensive delays in getting products to market and avoiding the financial and legal costs of non-compliance. The European Environmental Legislation/Standards are written by either CEN, CENELEC or ETSI as can be seen below.

Organisation	Members	Outputs
European Committee for Standardization (CEN)	National Standards Bodies of the 30 EU and EFTA countries + Croatia, FYR Macedonia & Turkey	European Standards (EN) Technical Specifications (TS) Technical Reports (TR) Guides
European Committee for Electrotechnical Standardization (CENELEC)	Same as CEN	Same as CEN
European Telecommunications Standards Institute (ETSI)	ETSI has more than 850 member organizations worldwide, drawn from 65 countries and five continents	European Standards (EN) ETSI Directives Technical Specifications (TS) Technical Reports (TR) Guides

EU Environmental Legislation/Standards covers a wide landscape dealing with defined areas (see table below). Management standards or more specifically environmental management is an important area where companies use standards to reduce the risk of environmental breaches or failures to comply with environmental regulation while enhancing the reputation of organisations. These are just some, there are a lot more standards being revised, and new standards being proposed all the time.

Environment	**Description**	**Typical Legislation/Standard**
Environmental Management	Product Foot printing Environmental Labelling Life Cycle Assessment	ISO 14001: Environmental Management
Climate Change & Energy	Greenhouse Gasses Ozone depletion Climate Change Resilience	ISO 50001: Energy Management ISO 14064: Greenhouse Gasses
Water, Marine & Fisheries	Marine Pollution	Water Framework Directive The Marine Strategy Framework Directive The Common Fisheries Policy
Industrial Pollution	Water Scarcity Water pollution Air Pollution	EU (Water Policy) Regulations EU (Drinking Water) Regulations Water Framework Directive Ambient Air Quality Directive EU National Emissions Ceilings Directive Part IV of The Environment Act 1995
Biodiversity	Conservation	EU 2020 Biodiversity Strategy
Waste Management	Waste Recycling Chemical Usage	WEEE Regulations REACH Regulation

	Control of Restricted Substances	RoHS2 Waste Framework Directive (2008/98/EC)
Mining	Conflict Minerals	Dodd-Frank Wall Street Reform and Consumer Protection Act OECD Guidance on conflict minerals
Packaging	Restricting the materials used for packaging	ISO 18600: Environment and Packaging Standards Ship Recycling Convention: Green Passport
	Ensuring high levels of protection for health and the environment	Classification, Labelling and Packaging (CLP) Regulation (1272/2008 EC)

Table 6: EU Environmental Legislation/Standards

European Directives - The European Parliament and Council of Ministers adopted a new Regulation on European Standardisation “Regulation (EU) No 1025/2012” in October 2012. This regulation cements the European Commission’s commitment to this regulation and to legislation in general. Although the European standards are the foundation on which the Single Market for products has been built over the past 20 years most standards developers are privately owned companies in whose work the societal interest may not be naturally represented. Through the Standardisation Regulation European standards developers have recognised the value that societal stakeholders can bring to the standards development process.

The main European directives/regulations are listed below:

1/ Directive 2011/65, EU, 'Restriction of the use of certain Hazardous Substances (RoHS2)'

2/ The European Chemicals Agency, (2014), 'Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)'

3/ Directive 2012/19/EU 'Waste Electrical and Electronic Equipment (WEEE)'

4/ Directive 2009/125/EC 'Eco-Design Directive'

5/ Regulation (EU) No 1025/2012, 'Of the European Parliament and of the Council on European standardisation, amending Council Directives'

6/ DECISION No 1386/2013EU, Of the European Parliament and of the Council on a General Union Environment Action Programme to 2020 'Living well, within the limits of our planet'

7/ Classification, Labelling and Packaging (CLP) Regulation (1272/2008 EC)

8/ Directive 2008/98/EC, The Waste Framework Directive (WFD)

Many companies are striving to obtain green certification and satisfy environmental legislation/regulation such as Waste of Electrical and Electronic Equipment (WEEE), Restriction of Hazardous Substances directive (RoHS), Energy Using Product (EuP) and End-of Life Vehicles (ELV), (Jeong, 2015).

Chemicals can be lethal to human health even if they do not ultimately result in death. Over the last thirty years continuous studies have shown that exposure to chemicals, sometimes at levels that was once considered safe are now interfering with our biological ability to remain healthy. Human health is deteriorating with increased cases of cancer (including child cancers), heart disease, respiratory conditions, reproductive deficiencies, learning and physical disabilities, allergies etc, all linked to exposure to chemicals. The two key pieces of legislation this thesis will address is REACH and the WFD, both pieces of legislation go hand in hand and supplement each other and both are essential to the Circular Economy. This does not mean that the other directives are not important but to remain within the constraints of this thesis the others are summarised.

4.1.9.1 **REACH**

REACH stands for Registration, Evaluation, Authorisation and Restriction of Chemicals, EC 1907/2006 is the number allocated to it. It entered into force on 1st June 2007.

REACH is a regulation of the European Union, adopted to improve the protection of human health and the environment from the risks that can be posed by chemicals, while enhancing the competitiveness of the EU chemicals industry. It also promotes alternative methods for the hazard assessment of substances in order to reduce the number of tests on animals (ECHA, 2019). REACH regulates chemicals manufactured, imported, and used in the production of finished goods placed on the market in the EU.

REACH is the result of a comprehensive drafting and consultation process run jointly by the Commission's Environment and Enterprise Directorates-General. The development of REACH included a White Paper and hundreds of meetings with stakeholders in industry, foreign trade partners and retail, consumers, environmental and welfare groups. In 2003, an internet-based consultation on a first draft was conducted which attracted over 6000 comments. Based on these comments the proposal was streamlined and formulated.

Although REACH entered into force in June 2007, the complexity of its requirements leads the EU to implement it in stages right up to June 2018. This philosophy meant that for the extensive number of stakeholders involved and the constraints on resources both regulatory and on industry, practical implementation became achievable. Companies may be legally obligated if a substance they are using is added to the Candidate List. These obligations may apply to the listed substance on its own, in an articled product or in a mixture. Before you can comply with the REACH regulation you need to know who you are as an Actor within REACH (i.e. Manufacturer, Importer, Distributor or Downstream user). REACH transferred the burden of proof of safety of chemicals from the government to the chemical manufacturers and downstream users.

The key steps involved in REACH are:

- **R**egistration of all chemical substances placed on the EU market in amounts greater than 1 tonne per year (per manufacturer or importer)
- **E**valuation of registration dossiers (for completeness and compliance, vertebrate animal testing plans) and prioritisation of substances for further evaluation
- **A**uthorisation of Substances of Very High Concern (SVHC), aimed at progressive replacement by alternative substances or technologies where viable.
- **R**estriction of **C**hemicals aimed at addressing risks not adequately controlled on a community wide basis (DEFRA. gov.uk).

Key Terms and Definitions

- Candidate List – a list of substances that have been assessed and reported as having serious effects on human health or the environment. These substances are classified as "Substances of Very High Concern" (SVHC's)
- Authorisation List – a list of SVHC's authorised for specific uses after consultation and assessment. The Authorisation process seen in Figure 4.20 aims to ensure that SVHC's are progressively replaced by less dangerous substances or technologies where technically and economically feasible alternatives are available. SVHC's are regularly assessed to determine which ones should be included in the Authorisation List – this is based on information in the registration dossiers and information received during the SVHC consultation period. A substance cannot be used without authorisation after the `Sunset date'.

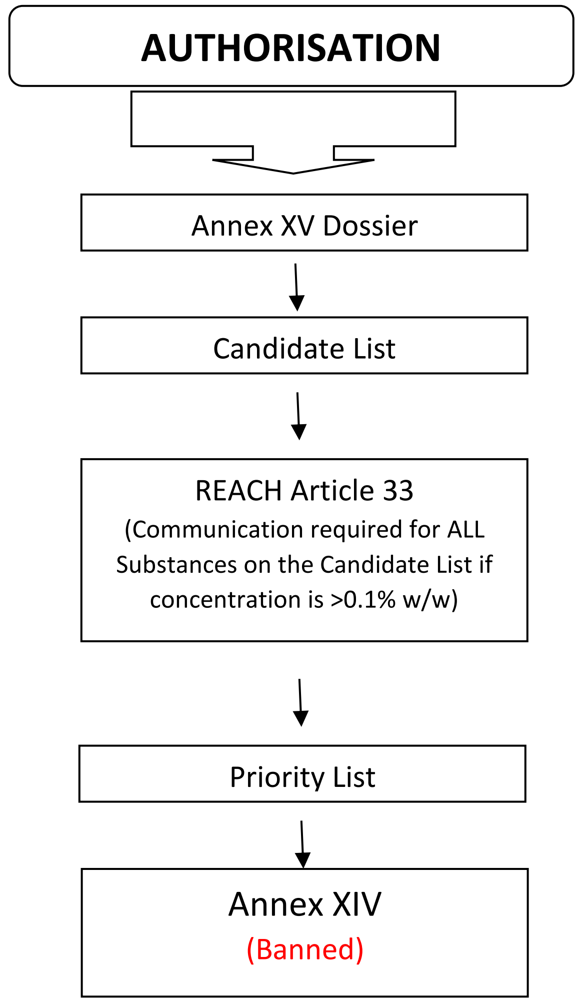


Figure 4.20: Authorization Process

- Sunset Date – the date from which the placing on the market and the use of a substance is prohibited, unless an authorisation is granted, or the use is exempt from authorisation.

- Restriction – is the process used to protect human health and the environment from unacceptable risks posed by chemicals. Restrictions are normally used to limit or ban the manufacture, placing on the market (including imports) or use of the substance, but can impose any relevant condition, such as requiring technical measures or specific labels. A restriction may apply to any substance on its own or in an article, including those that do not require registration, e.g., substances manufactured or imported below one tonne per year or certain polymers. Restriction of Chemicals are set out in Annex XVII of the REACH Regulation

Scope

Substances with the following hazardous properties may be identified as SVHC's:

CMRs – Under Article 57(a) means carcinogenic category 1A or 1B; Under Article 57(b) means mutagenic category 1A or 1B; Under Article 57(c) means toxic for reproduction category 1A or 1B.

PBT **-** Under Article 57(d) means persistent, bioaccumulative and toxic.

VPvB **-** Under Article 57(e) means very persistent and very bioaccumulative

ED **-** Under Article 57(f) means equivalent level of concern having probable serious effects to human health and/or the environment (adopted from ECHA, 2019).

The Candidate List is compiled as a list of substances that have been assessed and reported as having serious effects on human health or the environment. These substances are known as "Substances of Very High Concern" (SVHC's) and are candidates for inclusion in another list known as the "Authorisation List". Once they are on the Authorisation List, industry will need to apply for permission to continue using the substance after the sunset date. Organisations could suddenly find they now have obligations as a result of substances been put on the Candidate List. Any supplier of articles containing a Candidate List substance above a concentration of 0.1% (weight by weight) must communicate this to their customers down the supply chain and consumers. For importers and producers of articles containing an SVHC, they have six months from the date of its inclusion to notify the European Chemicals Agency (ECHA). "The Substances of Very High Concern" (SVHC) list also referred to as the "Candidate List". Substances of very high concern will be gradually identified in the 'Candidate List' and after consultation included in Annex XIV of the REACH Regulation. After inclusion in Annex XIV, they cannot be placed on the EU market or used after a date to be set (referred to as the "sunset date") except the company has received an authorisation to use. The authentic "Candidate List" is published on the European Chemicals Agency (ECHA) website.

The data set for analysis includes 205 substances, officially on the list, the list can be found in the Appendix.

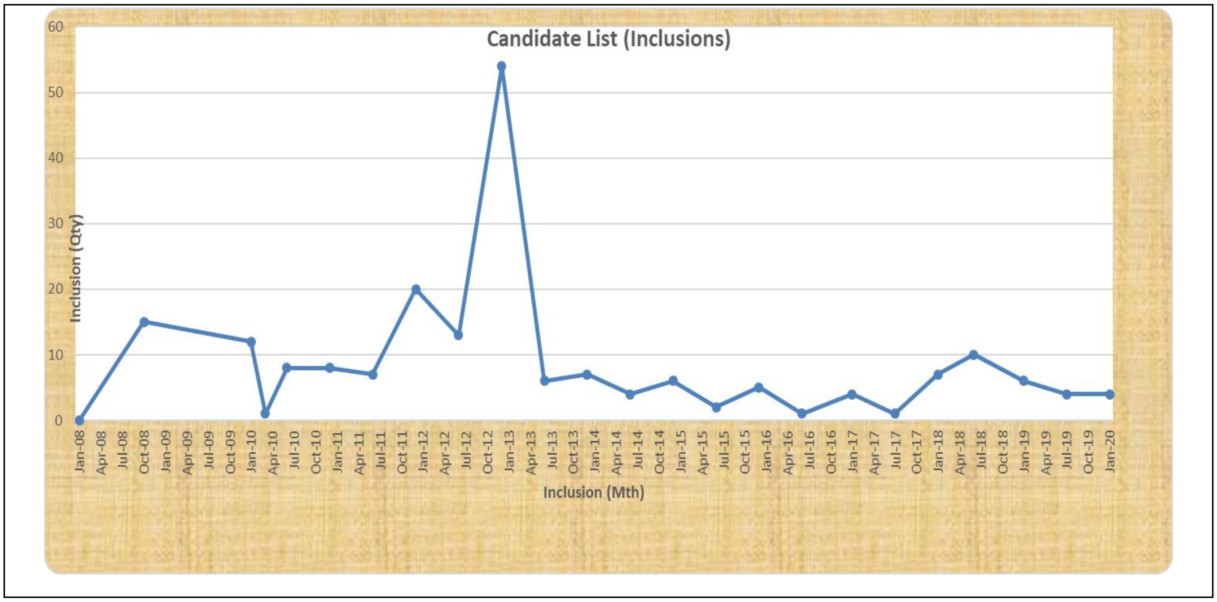


Figure 4.21: Candidate List (Inclusions) (based on ECHA SVHC list, 2021)

Any European countries, organisations, consumer groups etc can submit a substance dossier for consideration by the ECHA to go on the "Candidate List". This will give an indication of the countries, organisations, consumer groups etc likely to contribute to developing a standard on the CE and who will ultimately benefit from the published standard.

From Figure 4.21 Candidate List (Inclusions), you can see the inconsistency over the first seven or so years to a more settled consistency over the last six years. The Candidate List has new substances added to it every six months, which means you must assess your products against the new substances to ensure they are not in any of your products. The inclusions are important because it affects the resource efficiency of products in the Circular Economy.

Article 33 Ruling

- **Articles incorporated as components of a complex product must be notified to the European Chemicals Agency when they contain a SVHC in a concentration above 0.1%**
- What is an `**Article**'? - an `article' is an object which during production is given a special shape, surface or design which determines its function to a greater degree than does its chemical composition.
- Delta Mobrey products are an assembly of `articles' and therefore fall within the scope of Article 33 Ruling

Below is a typical route a manufacturer/supplier of articles might follow to comply with the REACH Regulation: It is important to gather available information on the substances and preparations used, how they are used and who supplies them. This information may be available both internally or externally and might include various departments within an organisation.

Supplier Questionnaire

- this needs to include specific questions on REACH, SVHC's and Article 33 Ruling
- this needs to request manufacturers details, their manufacturer's part number (MPN) and their supplier/s
- Questionnaires need to be sent to all suppliers and replies assessed and filed (Figure 4.22 below shows an example of a typical REACH questionnaire created by the writer)

Company Name: **Address:** **Contact Details:**

Materials Provided to (Company Name) from all Sites: Please provide details on types of electrical and/or electronic products, parts, components or any other materials in scope of the REACH regulation (EC 1907/2006) that you may supply to (Company Name). **LIST (Company Name) Part Nos.:**

REACH related questions	Yes	No
1. Is your company aware of REACH (EC 1907/2006) requirements including the European Court of Justice 2015 **Article 33 Ruling**?		
2. Has your company developed written policies and procedures for REACH compliance (EC 1907/2006)?		
3. Is your company aware of REACH SVHC's and the Candidate List substances?		
4. Does your company have procedures or systems for dealing with Articles and Substances containing an SVHC >0.1% w/w?		
5. Does your company receive any Statements, Declarations, or information on REACH from your suppliers?		
6. Does your company have procedures for dealing with your suppliers supplying you with Articles and Substances containing an SVHC >0.1% w/w?		
7. Does your company have any Registered substances under the REACH Regulation?		
7a. Have all substances that are contained in the material and require a registration been registered by your company or an actor up your supply chain?		
7b. If not, will all substances that are contained in the material and require registration be registered by your company or an actor up your supply chain by the relevant REACH Registration Deadlines?		
8. Do you supply (Company Name) with Article/s?		

9. Do you supply (Company Name) with Substances?		
10. Do you supply (Company Name) with any Article/s and Substances containing an SVHC >0.1% w/w?		
10a. If yes, please supply details.		
11. Would you be able to provide Material Safety Data Sheets (MSDS) if an Article or Substance supplied by you had an SVHC >0.1% w/w in it or if (Company Name) requested one?		
12. Do you foresee any changes (e.g., obsolescence) in future supplies to (Company Name) due to REACH?		
13. Do you have a written procedure to monitor future changes in the Candidate, Authorisation and Restriction lists?		
14. Do you have a written procedure to notify (Company Name) of any Article or Substance supplied containing an SVHC >0.1% w/w and change of status (i.e., no longer contains an SVHC >0.1% w/w)?		
15. Would you be able to supply (Company Name) with a copy of the written procedures in Questions 2, 4, 6, 13, and 14 upon request?		

Please identify your company's key departments involved in REACH compliance:

Department	**Yes**	**No**
Engineering		
Manufacturing		
Supplier Quality		
Compliance		
Regulatory		
Purchasing		

Other (please specify)		

Thank you for your cooperation. How many additional pages have you supplied? ☐

Figure 4.22: A Typical REACH Questionnaire

Purchase Orders

- the description on some purchase orders will have to be updated to reflect manufacturers details, their MPN and their supplier/s

BOMS

- need to be compiled showing part numbers and materials they are made off.
- need to know what articles are being purchased and match them to parts on BOMs - supplier name, code and MPN can be added to the BOMs spreadsheet.
- need to assess materials in the parts against the Candidate (SVHC) List

SVHC's

- If there are any parts with an SVHC in, then other actions are required including returning to the supplier and asking for a material data sheet, notifying customers and the Environment Agency or the Health and Safety Executive (if required)
- After notification there is a need to address the SVHC in the product
- the product can be replaced with a compliant purchased product.
- the material can be replaced for a similar performing material.
- the product /usage can be registered with ECHA (long and expensive process)
- If all else fails, then the product might have to be withdrawn.

Compliance

- If there are any parts with an SVHC in a concentration above the 0.1% w/w, as of the 5th of January 2021 then this information has to be submitted to ECHA for inclusion in the Substances of Concern In Products (SCIP) database

- It is not essential to remove the SVHC from the article providing notification is given to downstream users of its presence and it is added to the SCIP database.
- if there are no SVHC's in the product then the product can be declared as REACH compliant
- keep monitoring the SVHC List because substances are added to the list every 6 months.

Resources Needed

- Approvals – to do the material checks, spearhead the project and guide the other departments.
- Engineering – to help with the BOM's, drawings and material identification.
- Purchasing – to help with identification of the suppliers, questionnaires, and part descriptions to be updated on MRP and communicated to suppliers.
- Goods in – for any RoHS/REACH documentation delivered with articles.

The actions above are by no means complete, there will be the odd requirements not mentioned above.

Countries with similar REACH/chemical regulations.

- Australia – AICS (Australian Inventory of Chemical Substances)
- Canada – DSL (Canadian Domestic Substances List)
- Canada – NDSL (Canadian Non-Domestic Substances List)
- Korea – KECL (Korean Existing Chemicals List)
- Japan – ENCS (MITI) – (Japanese Existing and New Chemical Substances)
- Philippians – PICCS (Philippine Inventory of Chemicals and Chemical Substances)
- United States of America – TSCA (US Toxic Substances Control Act)
- Switzerland – SWISS (Giftliste 1)
- Switzerland – SWISS (Inventory of Notified New Substances)
- China – IECSC (Chinese Existing Chemical Inventory)
- Malaysia - EHSNR (Environmentally Hazardous Substances Notification and Registration)
- Turkey – KKDIK (The acronym in Turkish for REACH)

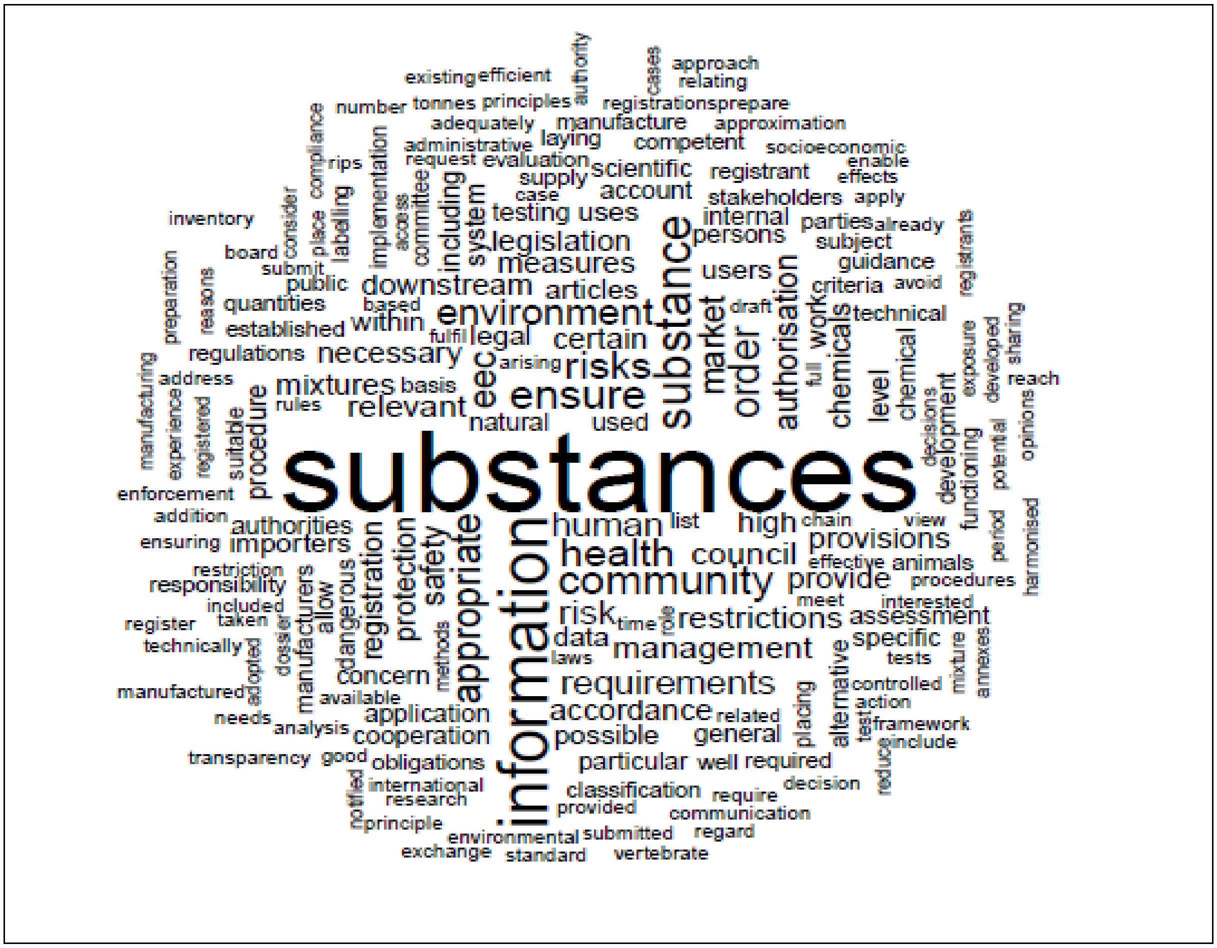


Figure 4.23: European Union REACH (based on the REACH Regulation)

The word cloud in Figure 4.23 has been generated using the text of EC 1907/2006 – the REACH Regulation, made into a text (.txt) file, cleaned then converted into a csv file and programmed into 'r'. The word cloud visually represents the frequency of words within a given body of text. "Often, they are used to visualise the frequency of words within large text documents, qualitative research data, public speeches, website tags, End User License Agreements (EULA's) and unstructured data sources" (Cool Infographics, 2020). The words which are more prominent than any other is substances and information, this is enough to pinpoint the fact that the information we have or do not have on substances being used or created in the European Union is critical to the health of the Union. The other main words from the word cloud like environment, health, community, data, management, requirements, restrictions, ensure, appropriate, order etc can be used as the framework to highlight the need to act on substance information in the EU. In, fact the Circular Economy relies on there being tight controls on substances especially when products are being recycled, redesigned, and reused. There is a dataset on REACH Substances of Very High Concern (for SVHC list -see Appendix).

Companies that produce, import or supply articles containing Candidate list substances have to submit information on these articles placed on the EU market to the Substances of Concern in Products (SCIP) database as of the 5th of January 2021 (eur-lex.europa.eu).

The main objectives of the SCIP database Figure 4.24 are:

1. To decrease the generation of waste containing hazardous substances by supporting the substitution of such hazardous substances.
2. To make information available to further improve waste treatment operations.
3. To allow monitoring of the use of SVHC's in articles by organisations authorised to monitor and to initiate any applicable action to achieve conformity to the directive.

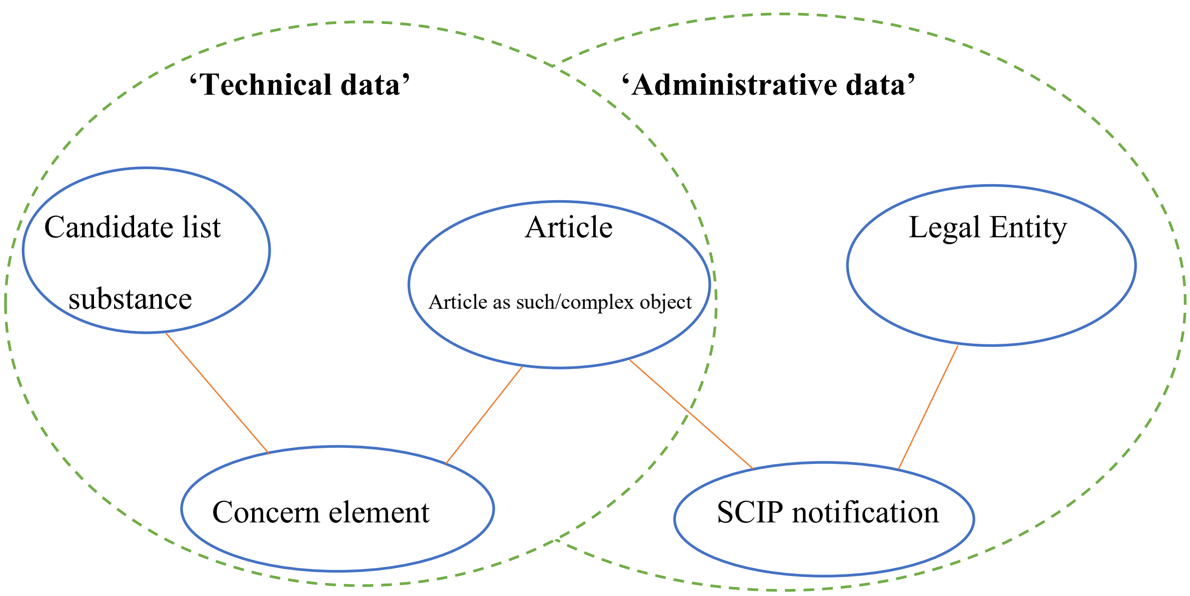


Figure 4.24: Main entities and their relationships in the SCIP data Model

(Source: echa.europa.eu, 2020)

The 7th EAP Decisions document (1386/2013/EU) – Priority objective 3, proposes to safeguard the Unions citizens from environment -related pressures and risks to health and well-being. It is basically a list of prioritised objectives that the EAP intends to use to achieve its 2020 Environmental goals under the theme of “Living well, within the limits of our planet”. The horizontal chemicals legislation (REACH) and the Classification, Labelling and Packaging (CLP) regulations, as well as legislation on biocidal products and plant protection products, provides baseline protection for human health and the environment, ensures stability and predictability for economic operators, and promotes the uptake of evolving non-animal testing methods. There is still uncertainty about the full effects of different chemicals (mixtures), nanomaterials, chemicals that interfere with the endocrine (hormone) system (endocrine disruptors) and chemicals in products. Research indicates that some chemicals have endocrine-disrupting properties that may cause several adverse effects on health and the environment, including with regard to the development of children, even at low doses and that such effects warrant consideration of precautionary action (EC, 2019).

It is a positive step to becoming a smart, sustainable and inclusive economy by 2020 with a set of policies and actions aimed at making it a low carbon and resource efficient Europe. These ideas fall in line with the concepts of the Circular Economy.

4.1.9.2 **The Waste Framework Directive** (WFD)

Directive 2008/98/EC, The Waste Framework Directive sets out measures addressing the adverse impacts of the generation and management of waste on the environment and human health, and for improving efficient use of resources which are crucial for the transition to the Circular Economy. As part of the implementation of the EU’s action plan for the Circular Economy adopted in 2015, the revised WFD entered into force in July 2018. It gave ECHA the task to develop a database with information on articles containing substances of very high concern and on the Candidate list under REACH. While its predecessor focussed on the disposal and recovery of waste, the 2008 Directive focusses on life cycle thinking. The Waste Hierarchy set out in Figure 4.6 is based on Article 4 of the WFD.

4.1.9.3 **Restriction of Hazardous Substances (**RoHS)

Restriction of Hazardous Substances, EU Directive 2011/65/EU. This Directive transitioned into UK law in 2012. The RoHS Directive applies to Electrical and Electronic Equipment (EEE) this refers to equipment which is dependent on electrical currents or electromagnetic fields in order to work properly and equipment for the generation, transfer and measurement of such currents and fields and designed for use with a voltage rating not exceeding 1000 volts for alternating current and 1500 volts for direct current.

The recast of the RoHS directive restricts ten substances in electrical and electronic equipment.

Restricted substances referred to in RoHS (2011/65/EU) Article 4(1) and maximum concentration values tolerated by weight in homogeneous materials are as follows:

1. Lead (0.1%)

2. Mercury (0.1%)

3. Cadmium (0.01%)

4. Hexavalent chromium (0.1%)

5. Polybrominated biphenyls (PBB) (0.1%)

6. Polybrominated diphenyl ethers (PBDE) (0.1%)

The below four substances have been added and shall apply from 22 July 2019

7. Bis (2-ethylhexyl) phthalate (DEHP) (0.1%)

8. Butyl benzyl phthalate (BBP) (0.1%)

9. Dibutyl phthalate (DBP) (0.1%)

10. Diisobutyl phthalate (DIBP) (0.1%)

A homogeneous material means - one material of uniform composition throughout that cannot be mechanically separated into different materials.

The restriction of DEHP, BBP, DBP and DIBP shall apply to medical devices, including in vitro medical devices, and monitoring and control instruments, including industrial monitoring and control instruments from 22 July 2021.

The restriction of DEHP, BBP, DBP and DIBP shall not apply to cables or spare parts for the repair, the reuse, the updating of functionalities or upgrading of capacity of EEE placed on the market before 22 July 2019, and of medical devices, and monitoring and control instruments, including industrial monitoring and control instruments, placed on the market before 22 July 2021.

Countries with similar RoHS Initiatives

- U.S/ California RoHS (SB20/SB50 Compliance – effective from January 1, 2007
- China RoHS Compliance – effective from March 1, 2007 (also see Chapter 4.5)
- Japan RoHS (J-MOSS) Compliance – amended 2001 law became effective July 1, 2006
- Taiwan RoHS Compliance – effective from December 1, 2016
- Korea RoHS Compliance – effective from January 1, 2008
- Norway RoHS Compliance (PoHS) is Prohibition on Hazardous Substances – effective from December 20, 2011
- India RoHS Compliance – effective from May 2014
- Ukraine RoHS Compliance - effective from March 10, 2017
- Singapore RoHS Compliance – effective from June 1, 2017
- UAE RoHS Compliance – effective from January 1, 2018
- Turkey RoHS Compliance – effective June 2019
- Eurasian/Russian RoHS Compliance – includes the Eurasian Economic Union (EEU) member states of Armenia, Belarus, Kazakhstan, Kyrgyzstan and Russia – effective from March 1, 2018
- Brazil RoHS Compliance – effective March 1, 2020

(rohsguide, 2020)

Most RoHS Compliance schemes around the world are based on EU RoHS which shows how highly regarded the EU RoHS compliance scheme is. More importantly it shows that the need to protect citizens and regulate harmful substances in products exists in every country.

4.1.9.4 **Waste Electrical and Electronic Equipment** (WEEE)

Waste Electrical and Electronic Equipment (WEEE) is regulated by the Directive 2012/19/EU of the European Parliament and the **recast** document was published in the Official Journal on the 4th of July 2012.

The purpose of this Directive is to contribute to sustainable production and consumption by, as a priority, the prevention of WEEE and in addition, by the re-use, recycling and other forms of recovery of such wastes, so as to reduce the disposal of waste and to contribute to the efficient use of resources and the retrieval of valuable secondary raw materials. It also seeks to improve the environmental performance of all operators involved in the life cycle of EEE, e.g., producers, distributers and consumers and those operators directly involved in the collection and treatment of WEEE.

Producers are responsible for financing, collection and recycling programs. The establishment, by this Directive, of producer responsibility is one of the means of encouraging design and production of EEE which considers and facilitates its repair, possible upgrading, re-use, disassembly and recycling (Directive 2012/19/EU).

This Directive shall apply without prejudice to the requirements of Union legislation on safety and health, on chemicals, in particular the EC 1907/2006 REACH Regulation, establishing a European Chemicals Agency, as well as of specific Union waste management or product design legislation (Directive 2012/19/EU).

This statement in the WEEE Directive is an example of how these documents (RoHS, REACH, Eco-design) support, compliment and contribute to each other’s purpose. It really goes to prove that the Circular Economy requires a systematic approach and many interconnecting documents to represent what a Standard on the Circular Economy would achieve.

Waste of electrical and electronic equipment such as computers, television sets, refrigerators and mobile phones is one of the fastest growing waste streams in the European Union, with some 9 million tonnes generated in 2005 and an expected growth to more than 12 million tonnes by 2020. WEEE includes most products that have a plug or need a battery and is a complex mixture of materials and components that due to their hazardous content if they are not properly managed can cause serious health and environmental problems. Consequently, the production of modern electronics requires the use of critical, scarce and often expensive materials. To improve the environmental management of WEEE and to contribute to the Circular Economy and enhance resource efficiency the improvement of collection, treatment and recycling of electronics at the end of their life cycle is essential. Every year an estimated 2 million tonnes of WEEE items are discarded by households and companies in the UK.

To address the problems created by the complex mixture of materials in WEEE the EU created this WEEE Directive and the RoHS Directive

4.1.9.5 **ECO-DESIGN**

Eco-design is regulated by the Directive 2009/125/EC of the European Parliament and the **recast** document was published in the Official Journal on the 21$^{st\ of}$ October 2009. "Eco - design" is the integration of environmental aspects into product design with the aim of improving the environmental performance of the product throughout its whole life cycle. The Directive establishes a framework for the setting of Community eco-design requirements for energy-related products with the aim of ensuring the free movement of such products within the internal market. Generic eco-design requirements aim at improving the environmental performance of products, focusing on significant environmental aspects thereof without controlling limit values (Directive 2009/125/EC). Eco-design regulates the design of the product in relation to energy efficiency and the products if properly eco-designed should meet defined energy efficiency standards.

Eco-design requirements facilitating the re-use, dismantling and recovery of WEEE should be laid down in the framework of measures implementing Directive 2009/125/EC. In order to optimise re-use and recovery through product design, the whole life cycle of the product should be considered (Directive 2012/19/EU).

4.1.9.6 **Conflict Minerals**

The purpose of legislation on conflict minerals is to try and eradicate funding to conflict affected areas by disrupting the market for conflict minerals from identified mines. In 2010 the United States of America (USA) passed legislation, known as the Dodd Frank Act Section 1502, which requires US-listed companies to carry out due diligence on minerals sourced from the Democratic Republic of Congo (DRC) and neighbouring countries. The EU has also developed regulation on conflict minerals that come into force on the 1st of January 2021. The regulation covers the same minerals as the Dodd Frank Act and requires EU organisations in the supply chain to ensure they import these minerals and metals from responsible and conflict free sources only.

The minerals regarded as Conflict Minerals are Tin, Tantalum, Tungsten and Gold, commonly known as 3TG. These minerals are commonly used in everyday consumer products such as cars, mobile phones and jewellery.

4.2 What is the role of Diversity in the Circular Economy?

4.2.1 **Introduction**

The Circular Economy takes a holistic approach to the design and use of the products, materials and resources we use daily to maximise their value before we eventually dispose of them. The concept is to conserve and re-use resources through the introduction of multiple product life cycles rather than the linear model of a "take, make and dispose "off philosophy. This holistic approach kindly lends itself to the "diversity" found in the Circular Economy. Systems which are diverse in terms of connections and scale are resilient in the face of unexpected external influences.

The concept of the CE has been developed through different approaches from disciplines such as ecology, engineering, design, economics and business, so it has developed from a multidisciplinary perspective.
Despite their different assumptions and strategic intentions, the concepts of the Circular Economy, the Green Economy and the Bio Economy are joined by a common ideal, to reconcile economic, environmental, and social goals. These three concepts are currently mainstreamed in academia and policy making as key sustainability avenues (D'Amato, 2017).

Diversity is important because it provides options for responding to change and disturbance. Diverse systems with many different components are generally more resilient than those with few or less diverse components. Diversity can be split into three compartments, they are:

Variety – how many different elements are there

Balance – how many representatives of each element are there

Disparity – how different the elements are from each other

Figure 4.25 below supports the concept of eco-effectiveness by purporting the transformation of products and their associated material flows such that they form a supportive relationship with ecological systems and future economic growth. It supports an economy where society uses resources efficiently to enhance human wellbeing while maintaining the natural systems that sustain us. It is, so important to maintain an optimal balance – too little diversity and we head towards brittleness and too little efficiency, and we dive towards stagnation. To become resource efficient, we need to produce and consume in a way that optimises the use of all resources involved. The efficient use of resources benefits the economy and society in the long term by protecting the world we all live in and reduce the dependency on overuse of raw materials and natural resources. Resource efficiency contributes to avoid depletion, degradation or a collapse of ecosystems.

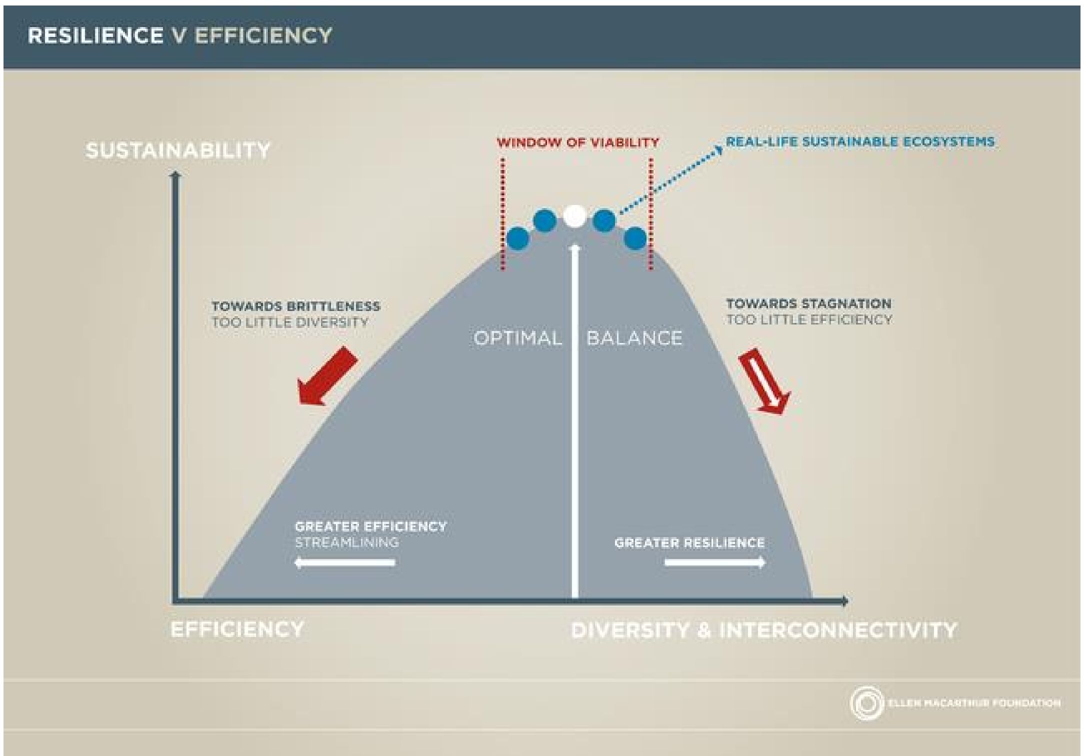


Figure 4.25: Resilience vs Efficiency (EMF4, 2012)

Figure 4.25 above, from the Ellen MacArthur Foundation (EMF) ties their thinking on the Circular Economy with the concept of being resilient and efficient, restorative and regenerative by design, keeping products, components and materials at their highest usage and value always. The EMF acknowledges the role of intelligent assets and connectivity in the proliferation of the CE. At the end of the chapter is presented three data science technologies, the third NLP being very new.

4.2.2 **The Circular Economy – Schools of Thought**

The CE schools of thought fit perfectly into this Chapter because of their diverse nature. The practical applications now becoming necessary in the 21st century were the results of a small number of academics, thought leaders and businesses. These general concepts have been innovated, adapted and modernised to fit today's systemic thinking.

These Schools of thought are:

- *Regenerative Design* – In the 1970's American Professor John T. Lyle launched a challenge for graduate students to forge ideas for a society in which daily activities were based on the value of living within the limits of available renewable resources without environmental degradation. The term regenerative design came to be associated with this idea – that all systems, from agriculture onwards, could be orchestrated in a regenerative manner (i.e. that processes themselves renew or regenerate the sources of energy and materials that they consume).
- *Performance Economy* – Walter Stahel architect and industrial analyst, sketched in his 1976 research report to the EC, The Potential for Substituting Manpower for Energy, co-authored with Genevieve Ready, the vision of an economy in loops (or circular economy) and its impact on job creation, economic competitiveness, resource savings and waste prevention. The four main goals of Stahel's school of thought are:
    - Product life extension
    - Long-life goods
    - Reconditioning activities
    - Waste prevention
- *Cradle to Cradle* – German chemist and visionary Michael Braungart went on to develop, together with American architect Bill McDonough, Cradle to Cradle concept and certification process. The Cradle-to-Cradle framework focusses on design for effectiveness in terms of products with positive impact, which fundamentally differentiates it from the traditional design focus on reducing negative impacts.

- *Industrial Ecology* – is the study of material and energy flows through industrial systems. Its international society is headed by Professor Roland Clift at the University of Surrey. It focusses on connections between operators within the industrial ecosystem, this approach aims at creating closed loop processes in which waste serves as an input, thus eliminating the notion of an undesirable by-product. This framework is sometimes referred to as the 'science of sustainability', with an emphasis on natural capital restoration, industrial ecology also focusses on social wellbeing.
- *Biomimicry* – authored by Janine Benyus, defines her approach as a new discipline that studies natures best ideas and then imitates these designs and processes to solve human problems. She thinks of it as innovation inspired by nature. Biomimicry relies on three key principles, these are:
    - Nature as model – study nature's models and emulate these forms, processes, systems and strategies to solve human problems.
    - Nature as measure – use an ecological standard to judge the sustainability of our innovations.
    - Nature as mentor – view and value nature not based on what we can extract from the natural world, but what we can learn from it.

(Based on EMF1, 2015)

4.2.3 **The Circular Economy as an Ecology**

Ecology – is the study of the relationships between organisms and their environment. Some of the most pressing problems in human affairs – expanding populations, food scarcities, environmental pollution including global warming, extinctions of plant and animal species and all the attendant sociological and political problems are to a great degree ecological (Smith, 2020).

It is obvious but not often appreciated that ecologies do not exist on their own, but rather they live together in populations of the same species or make up and in communities of different species or make ups, interacting with each other and their physical surroundings in a respectfully intimate and complex way. The same is true in a Circular Ecology. Competition and cooperation among species occur naturally in the wild, thus maintaining the efficiency of natural ecosystems and certainly providing the flexibility and adaptability for survival. But the world is constantly changing, the weather patterns have become more erratic, and patterns of droughts and floods are becoming commonplace. The era of post-war consumerism, where people capitalised on a world rich in natural resources, that were and still is by many thoughts to be endless is closing as our ecological limits appear ever closer. People are turning resources into waste faster than nature can reverse this trend and nature can turn waste back into resources. Ecosystems provide us with materials, food, clean air and water, outdoor activities and assimilate air pollution and wastes. The ecosystems do not get the opportunity to circulate and so the Circular Economy is needed to avoid total collapse of our ecosystems.

Circular Economy systems keep the added value in products for as long as possible and eliminate waste. They keep resources within the economy when a product has reached the end of its life, so that they can be productively used again and again and hence create further value (EC, 398, 2014). As defined before in the introduction - the Circular Economy is an industrial system that supports a restorative concept through intelligent design of materials, products and systems and the business model. This allows us to use the systems way of thinking to expound the concept of the Circular Economy.

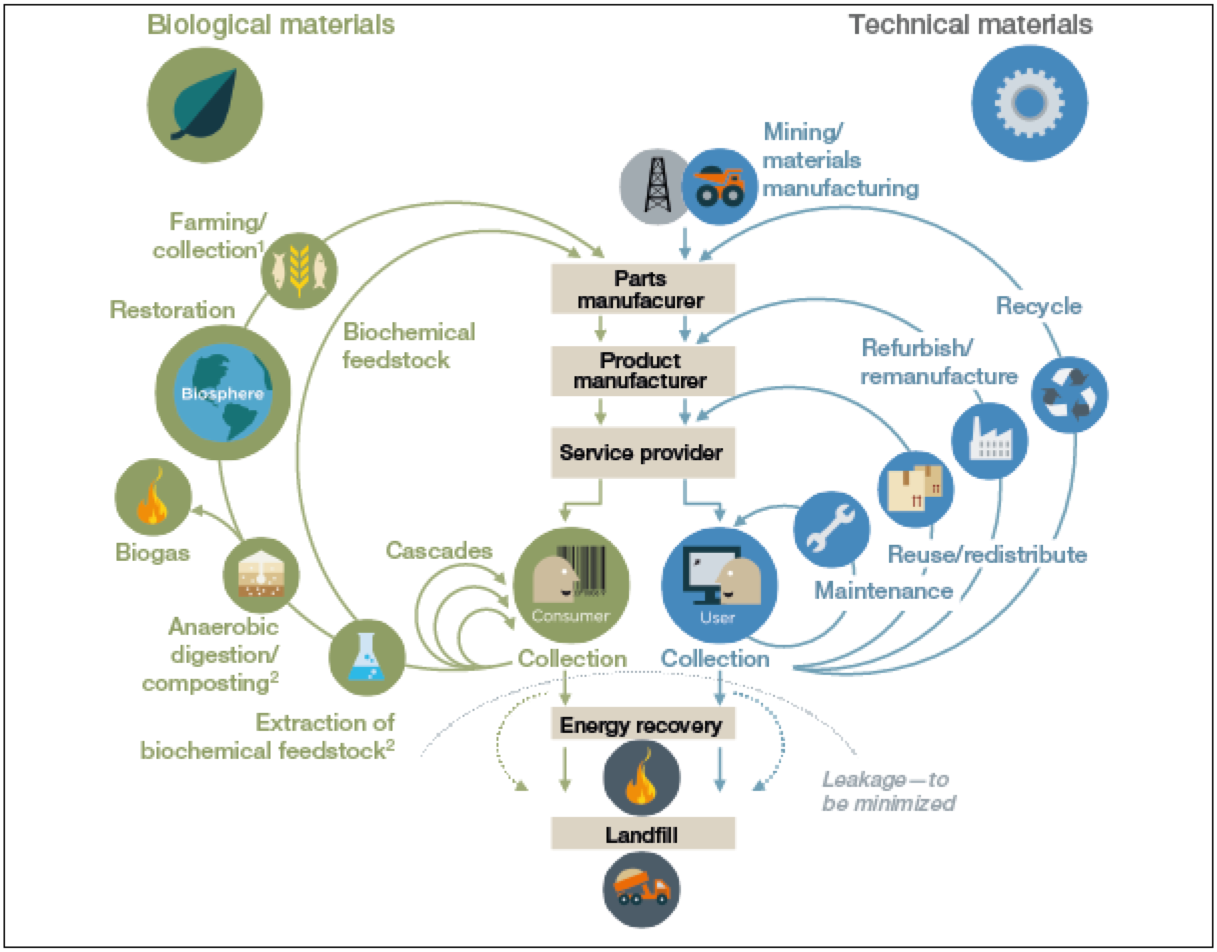


Figure 4.26: The Circular Economy as an Industrial System

(EMF1, 2015)

The two major cycles seen in Figure 4.26 are the Biological and the Technical. The biological materials cycle revolves around how waste can build capital rather than reduce it. It can do this by rethinking and redesigning the products and their packaging so that once their lifetime is over, they can be safely returned to the soil and easily degrade, without causing much damage to the environment. Problems begin to surface when there are products that do not biodegrade, like some plastics and electronics. The technical materials cycle is there to deal with these non-biodegradable products by repairing, reusing, recycling, refurbishing these products so that they continue to be useful beyond their end of life, yet ensuring availability of their constituent raw materials. The Circular Economy as an Industrial System - demonstrated in Figure 4.26 is based on the principles of:

1. Designing out waste
2. Circularity

3. Energy consumption

Designing out waste – an absolute key feature of the Circular Economy is to design out waste, products need to be designed for a cycle of disassembly and reuse. Designing products that are easier to recycle, repair, remanufacture, upgrade or maintain. The designer must consider the mechanical and chemical composition of the materials being used so choices can be based on Circular Economy aims.

Circularity – the precise product cycles in Figure 4.26 summarize the Circular Economy and separate it from disposal and possible even recycling, large amounts of expectant energy usage and labour are removed. Circularity allows there to be differentiation between consumable and durable products. Consumables mostly consist of either biological or technical materials. The biological materials are mainly non-toxic and thus capable of being returned to the biosphere without any or with little decontamination, whereas the technical materials are unsuitable for the biosphere and should be designed from the start to be reused, recycled, refurbished and so on.

Energy consumption – the energy sources should be renewable with capability of energy recovery (e.g., solar, wind, hydro, biomass). Energy usage per unit of output should be reduced with an accelerated shift towards using renewable energy. Energy consumption needs to be considered holistically or as a system, because the thinking here should comprise all the processes and infrastructures that exist in connection with the resource. An energy system, for example includes the types of energy we use (natural gas, oil, wind power, solar power, to a lesser extent coal, etc), how we extract or generate this energy (wind turbines, oil wells, fracking, shale gas, etc), where we use it (transportation, manufacturing, essential services, households, etc) and how it is distributed (gas cannisters, petrol stations, domestic gas supplies, etc). A large system of interventions is beginning to emerge. This system would also need to address other issues such as the land and water resources affected by the energy consumption and energy production.

Sustaining the virtuous loops of production and exchange poses a particular problem because they eventually reach their limits. At some point, the extra cost of improving and refining further a circular material flow will exceed the corresponding benefits to society, and this is true for any kind of environmental protection. Specifically, a Circular Economy must promote loops when socially desirable and efficient, i.e., if the benefit is greater than or equal to the cost (Sauve, 2015).

Systems thinking is about understanding the often complex, nonlinear, and interconnected system in which an organization operates. Many large organizations and even some SMEs are complex, adaptive systems in themselves, meaning that the elements that make up an organization have a complex set of interactions that are dynamic and so do not always interact in the same or consistent way. Organizations require techniques for managing these interactions effectively. This makes the organization adaptive in nature so that it responds according to the needs or circumstances at the time. Thinking about relationships within a system is crucial to understanding how a company creates value and how it might be able to intervene in the "system" to influence the sustainable management of resources in its portfolio of products and services (Pesce, 2020).

Systems thinking can help users to consider the full set of interactions and interdependencies affecting their organization, including influences within and from outside the context within which the organization operates. Systems thinking can help to identify positive and negative feedback loops that can attenuate or exacerbate the impacts of change. Similarly, systems thinking can help identify unintended consequences of decisions or actions before they are implemented (EN ISO 14090, 2019). Systems thinking focuses on non-linear systems in which feedback loops play a fundamental role. In these systems, the combination of uncertain environmental factors and feedback give an unpredictable outcome. But thinking about these relationships and materials flows is crucial for understanding how the system can be optimised. This requires a long-term focus. At various levels of scale, systems influence each other, and relationships of dependency and feedback loops exist that contribute to the resilience of the Circular Economy (EC, 2015).

Systems thinking becomes very important in managing waste regardless of whether it is product, construction or food waste. There needs to be a system in place not only to reduce waste but also to remove it to manageable sites in or outside cities.

Once in the Netherlands, there was a strike of waste collectors. The cities in the Netherlands looked much like the developing world and you realize cleanliness have to do with the performance of the system as a whole system. If one parameter is not working in waste collection, it will look like the developing world in that moment. You need to tackle all of those parameters to impact waste management system performance, not just one or two (Morgan, 2015). In a world where everything is connected, quantification of impacts separately and isolating each from the bigger system can mislead our decisions about products, services or goods. Therefore, systems thinking plays a vital role to bridge different systems, disciplines and methods. A strong understanding of systems thinking is essential for the LCA and CE communities, as well as decision-makers from industries and government organizations (Onat, 2017).

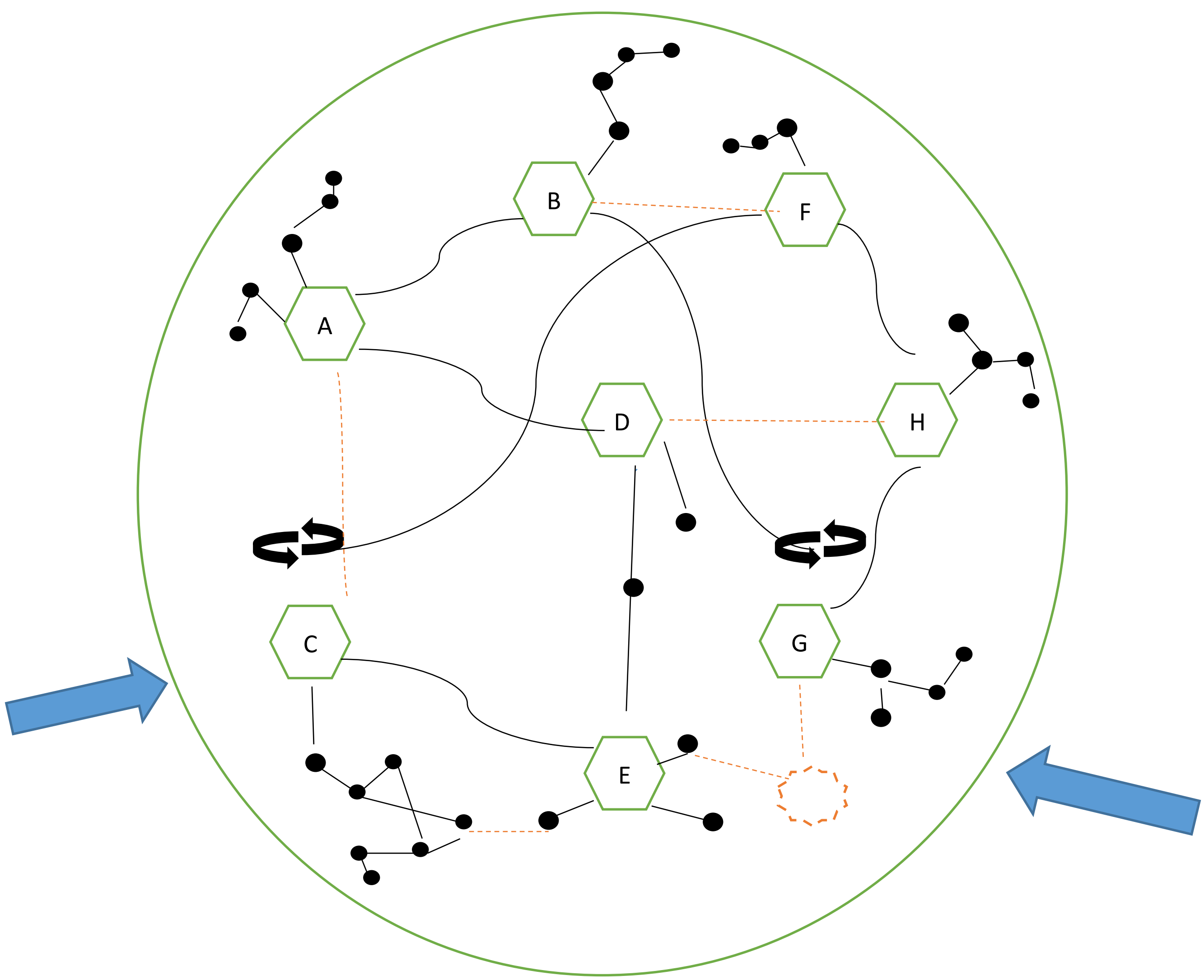
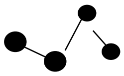


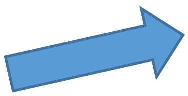
Figure 4.27: Systems concept showing a general systems concept with highlighted interventions.

Key:

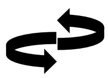
An organization: one part of a system



Key actors or stakeholders, e.g., regulators, suppliers, communities, NGO's, technology providers, clients.



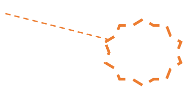
External factors, e.g., environmental constraints, policy and regulation, consumer preferences, advances in technology.



Feedback loops, e.g., new communication channels, new relationships, customer feedback, recycling or reuse of products and materials, wider social values.

System boundary, e.g., geographical/place based, sector, market.

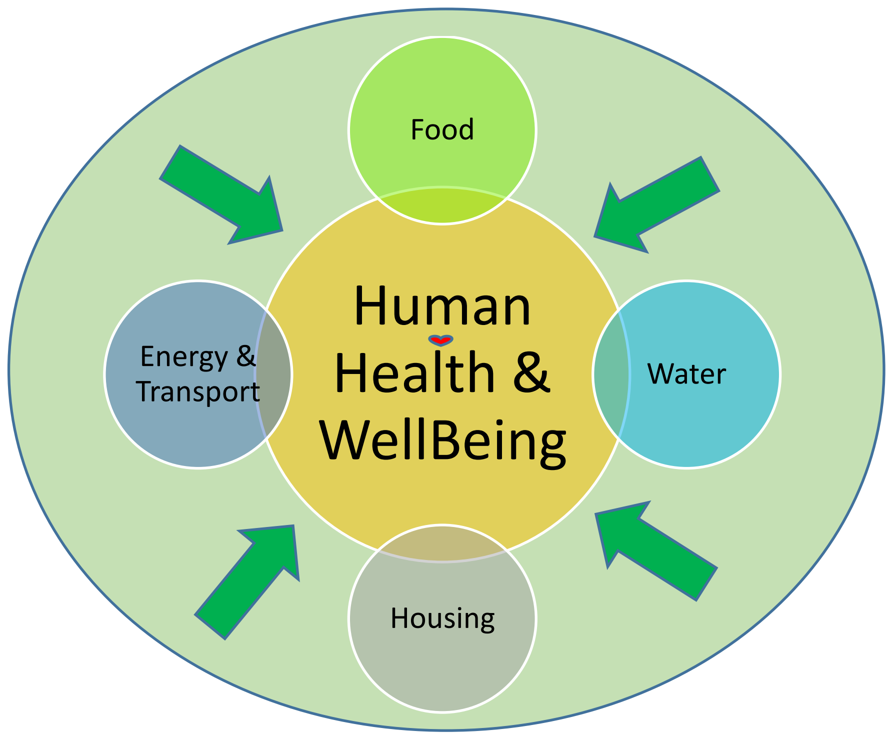
Relationship link, e.g., formal (contractual, transactional) and informal (knowledge exchange, business support, community relationships.



Systematic intervention: new inputs, changing the total output of the system, e.g., standards or rating schemes, policy changes, product or service innovation, business model innovation, increase access to solutions, reshape supply, create user demand and implement new platforms.

(re-drawn and based on EN ISO 14090, 2019)

Thinking about interconnected relationships in a system is crucial for understanding how an organization might be able to intervene in the system to influence the sustainable management of resources in its portfolio of activities, products, and services. Dependencies are one-way interconnections, meaning that organization A depends upon a product or service from organization B, but not the other way around; whereas interdependencies are two-way interconnections, meaning that organizations A and B depend on each other.



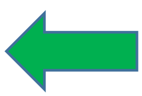
 - Outer boarder represents the Environment

Figure 4.28: A typical example of Systems Thinking Circular Ecology of interdependencies.

The above Figure 4.28 has been designed to show a typical example of how the environment and our health and wellbeing are connected but also how the natural resources (food, water, housing, energy and transportation) incite our production and consumption and create economic wealth and jobs that define our quality of life and wellbeing. The natural resources sit within the environment and create these interdependencies. People must live within the environment and natural ecosystems, which is different across the world but systems thinking helps the perception of how and why these systems exist and how they are impacted. The study on ICT reuse in socio-economic enterprises was designed to determine the impacts of the repair, refurbishment and reuse of ICT products. The study highlighted that the long-term economic viability of these organisations may be uncertain; promotion and advertising of their services, widening sources of reuse products, adoption of standard quality certification and better access to potentially reusable equipment can help improve their economic standing. The study also highlighted the potential to contribute to a closed-loop economy (Ongondo, 2013).

4.2.3.1 **Closing Loops**

Cycles, such as of water and nutrients, abound in nature – discards become resources for others. Yet humans continue to make, use and dispose. One -third of plastic waste globally is not collected or managed. There is an alternative; A Circular Economy would turn goods that are at the end of their service life into resources for others, closing loops in industrial ecosystems and minimizing waste (Stahel, 2016).

Using resources for the longest time possible could cut some nations emissions by up to 70%, increase their workforces by 4% and greatly lessen waste.

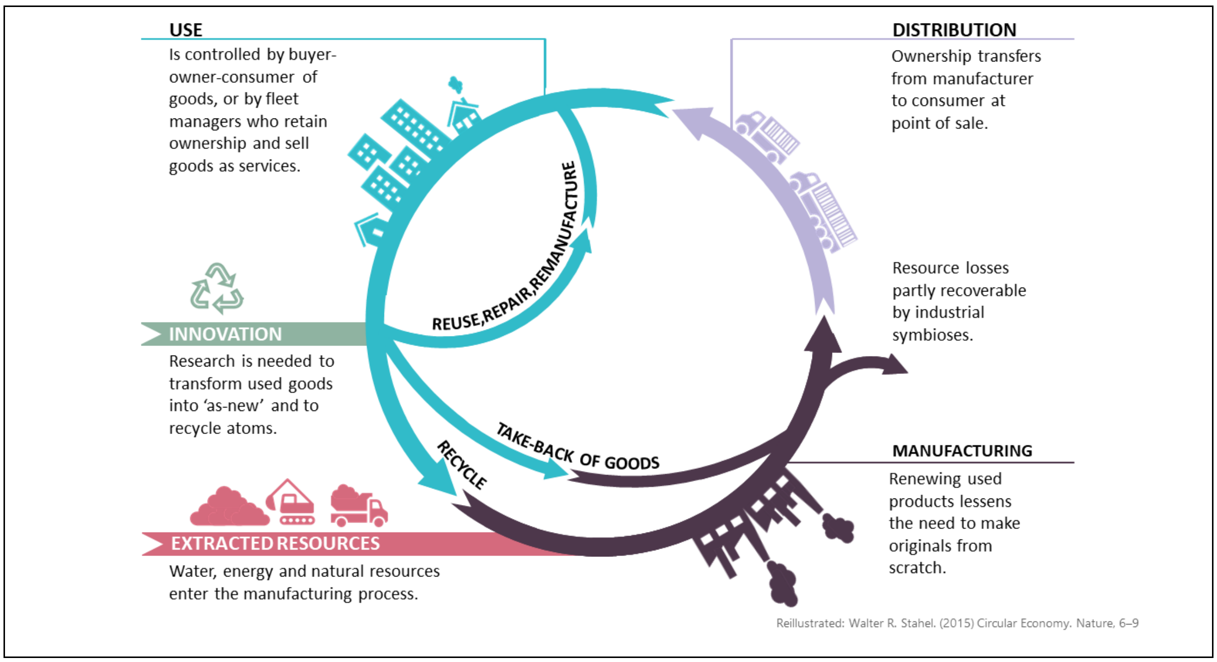


Figure 4.29: Closing Loops (Stahel, 2016)

In Figure 4.29 above we can see how Stahel represents the material flows to demonstrate how production and consumption generate as little losses and waste as possible. Innovation plays a huge part in finding solutions to industry needs but in specific ways to maximise the efficiency of the cycle. Manufacturing then must produce these inventions paying particular attention to the material flows, and by-flows of the raw materials being used, efficiently as possible.

An example of a country using this closed loop material flow, but as a management tool is Germany. The new German Closed Cycle Management Act is aimed to turn the waste management into a resource management. The waste management policy, which has been adopted in Germany over the past 20 years is based on closed cycles and assigns disposal responsibilities to manufacturers and distributers of products (Nelles, 2015).

An example of an organisation using this closed loop material flow is Tarkett – they offer one of the largest portfolios of flooring and sports surface solutions in the industry. They believe in "Doing Good Together" and are committed to building a healthy Circular Economy.

A breakthrough for the Circular Economy was recently made by fully closing the loop on the life cycle of commercial carpet tiles in Europe through a pioneering partnership with another company that produces fibre. This collaboration is now generating two material streams (yarn and carpet tile backing), which can then be recycled and transformed into high quality secondary raw materials to produce new yarn and carpet tiles (Tarkett, 2020). Modern closed cycle management contributes approximately 20 per cent to achieving the German Kyoto targets on the reduction of climate-relevant emissions. European countries that are less confident with their waste reduction and climate-relevant emissions should look to Germany for inspiration on how to achieve this closed cycle management system.

4.2.4 **The Ecological Footprint**

Since the 1970's, there has been a global overshoot (the ecological footprint of the world population is larger than nature can cope with), and now we are using roughly one and a half times the earth's biocapacity per year. The Ecological Footprint is the metric that measures how much nature we have and how much nature we use. It measures the ecological assets that a defined population requires to produce the natural resources it consumes. This includes plant-based food and fibre products, forestry products, fish and products from the sea, livestock and infrastructure excesses.

Our ecological footprint is a combination of all the things we do that require us to draw on natural resources. It includes the impact from our homes (e.g., the oil, gas and electricity we use), transport (e.g., car, train and plane trips), food (e.g., land under cultivation and fertilisers), and consumer goods (e.g., fossil fuel used to make and transport goods). In addition, it includes the fossil fuel energy and built land required by government and business to provide infrastructure, goods and services. An ecological footprint will show, under prevailing technology, how much land and water area a human population requires to provide the resources it consumes and to absorb its waste (WWF, 2012).

Different countries have different footprints, an individual's ecological footprint varies significantly depending on several factors, including their residential country, the quantity of goods and services they consume, the resources used, and the wastes generated to provide these goods and services. The size of a person's ecological footprint depends on development level and wealth, and in part on the choice's individuals make on what they eat, what products they purchase and how they travel. But decisions undertaken by governments and businesses have a substantial influence on the ecological footprint too, therefore governments and businesses play an important role in reducing the ecological footprint (WWF, 2012).

The Ecological Footprint tracks the use of six productive surface areas: grazing land, agricultural land, fishing grounds, built-up land, forest land and carbon capture land.

Grazing Land is the amount of grazing land used to raise livestock for meat, dairy, hide and wool products.

Agricultural Land is the amount of agricultural land used to grow crops for food and fibre for human consumption as well as for animal feed oil crops and rubber.

Fishing Grounds is calculated from the estimated primary production required to support the fish and seafood caught, based on catch data for marine and freshwater species.

Built-up Land is the amount of land covered by human infrastructure, including transportation, housing, industrial structures and reservoirs for hydropower.

Forest Land is the amount of forest required to supply timber products, pulp and fuel wood.

Carbon Capture Land is the amount of forest land that could isolate CO_2 emissions from the burning of fossil fuels, excluding the fraction absorbed by the oceans which leads to acidification. The damage of excess greenhouse gases that cannot be absorbed by vegetation are already being seen, with rising levels of atmospheric CO_2 causing climate change, increased global warming and ocean acidification.

Forest land and carbon capture land make demands on forests that are unique to their individual functions – the unharvested forest functions as a carbon capture but when harvested it releases the captured CO_2 again.

For comparability across the area types and countries, the Ecological Footprint and Biocapacity (a measure of the amount of biologically productive land and sea area available to provide the ecosystem services humanity consumes) are expressed in units of world-average bio productive area, referred to as global hectares (gha).

The Ecological Footprint is further diagrammatically represented below for more clarity in Figure 4.30.

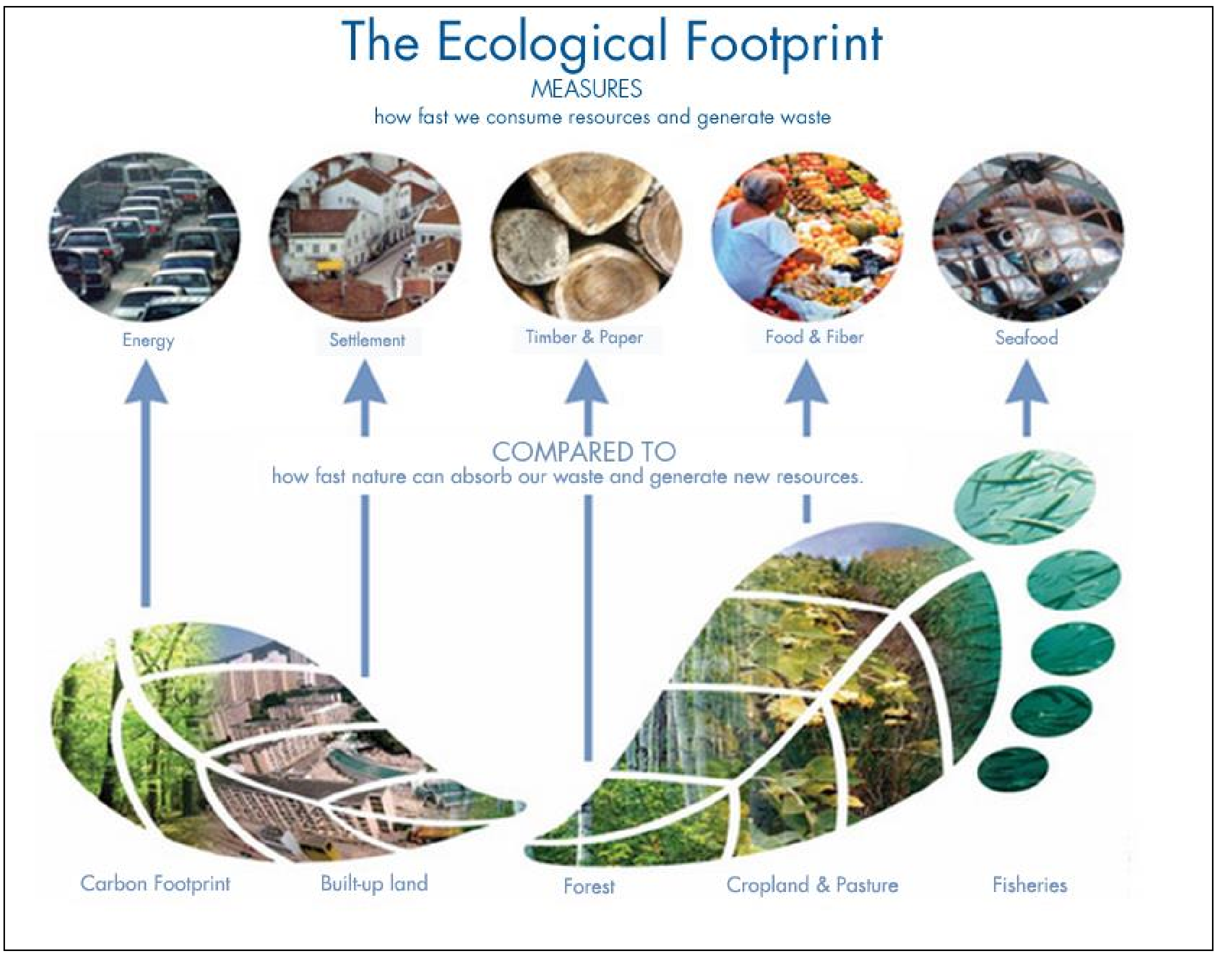


Figure 4.30: The Ecological Footprint (Footprint Network, 2012)

Just looking at the ecological footprint diagram Figure 4.30 you can see similarities with the linear economy where we take, make, and dispose of products at an unsustainable rate. This form of production and consumption is exactly what the Ecological Footprint and the Circular Economy is actively discouraging.

EU-27 (2005)	**Ecological Footprint**		**Biocapacity**			**Difference**	
Land Type	Global ha /person	Global ha (Million)	Global ha /person	Global ha (Million)	%	Global ha /person	Global ha (Million)
Cropland	1.17	570.1	1	487.3	43.3	-0.17	-82.8
Agricultural Land	0.19	92.5	0.21	102.3	9.1	0.02	9.7
Forest Land	0.48	233.9	0.64	311.9	27.7	0.16	78
Fishing Grounds	0.1	48.7	0.29	141.3	12.6	0.19	92.6
Built-up Land	0.17	82.8	0.17	82.8	7.4		
Carbon Capture Land	2.58	1257.2				-2.58	-1257.2
Total	**4.69**	**2285.2**	**2.31**	**1125.6**	**100**	**-2.38**	**-1159.7**

Table 7: The Ecological Footprint of EU-27 (Biois, 2011)

The rising ecological footprint emphasize the need for more sustainable policies. Efficient circular production systems would positively lower humanity's ecological footprint to within ecological limits by reducing the human demand for natural resources, land, water and energy. Efficient circular production systems can help humanity make better informed choices for the future and highlights how important it is to conserve biodiversity and protect ecosystem services. This becomes poignant in the light of population increase and the need to meet the needs of the developing and poor countries of the world.

According to the United Nations Food and Agriculture Organization (FAO), demand for food, feed and fibres could grow by 70% by 2050. This has considerable implications for land use and natural ecosystems and, also for the size of humanity's ecological footprint (Footprint Network, 2012).

4.2.5 **The Circular Economy and Reverse Logistics**

Reverse Logistics (RL) – is the handling of the return flows of a product or equipment back from the consumer for reuse, recovery or recycling. Correctly managing the activities around RL provide for the recycling and removal of waste within the returns as shown in Figure 4.31. If products can be designed so they can be recycled and reused, then RL definitely contributes to reducing the need for extraction of raw materials from the environment. This concept feeds into the life cycle monitoring of products after they arrive at the end user. Making reverse logistics and remanufacturing work, requires solving various problems including the fluctuating demand and supply of used products and components and the widely varying condition of the returned components (Charnley, 2019).

Figure 4.31: Reverse Logistics (Newcastle Systems, 2017)

Ripanti's 2016 research paper adopts the product remanufacturing activities associated with CE principles, most of the principles are a given but the ninth principle is technology driven. Such technology includes data collection, data visualisation using data science tools and software.

The CE is closely associated with green supply chains i.e., supply chains that practice environmental sustainability. In transport and logistics, it is necessary to remember that the organisations approach to the appropriate management of packaging products in the phase of storage and disposal is one of the basic criteria during assessing the company's environmental impact. This aspect should be particularly important for companies that want to implement not only the eco-friendly business models, but also the idea of a Circular Economy (Turon, 2016).

4.2.6 **The Relationship between Reverse Logistics and the Circular Economy**

There are similarities with RL and the CE. Some CE activities like maintenance, collection, repair, refurbishment, remanufacturing, recycling etc are mirrored by similar RL activities like direct reuse/resale, repair, refurbishment, remanufacturing, cannibalisation, recycling etc. The purpose of RL is to produce an efficient and effective process of planning, implementing, and controlling the flow of material to recapture the values of proper disposal. While the CE's purpose is to keep products in their highest utility and value in the circulation by distinguishing between biological and technical materials (Ripanti, 2016). In Figure 4.32, you can see where the similarities exist, but the CE allows the raw materials to re-enter the process at different points depending on which CE principle is applied. Reverse cycle infrastructure and logistical capabilities are crucial to close the geographical imbalance between remanufacturing and usage. The infrastructure needs to ensure that costs do not eliminate the positive arbitrage opportunities, that is the difference between recovered and raw materials, components and products. In the linear economy transportation to landfill and incinerators is often local, with little or no ability to handle different types of materials or sort them carefully enough to maintain their recycling quality at scale or without breaking them down first. However local recycling centres are getting better at this. Despite various constraints, organisations involved in the reuse of equipment (e.g., ICT equipment) could contribute significantly to resource efficiency and a CE.

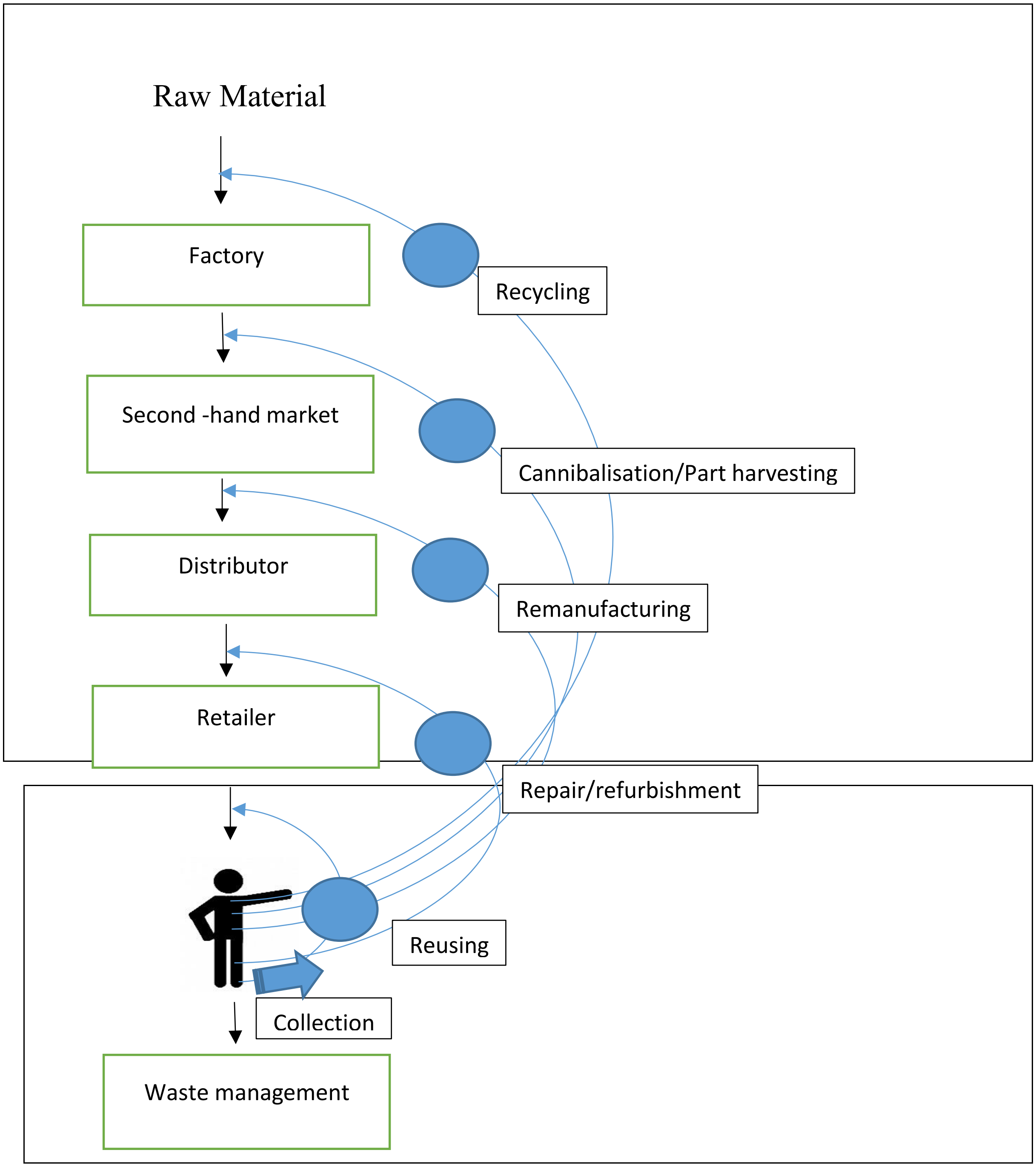


Figure 4.32: Relationship between the Circular Economy and Reverse Logistics

(Redrawn based on: Ripanti, 2016)

4.2.7 **The Circular Economy at Different Levels**

Prieto-Sandoval describes the CE as a cycle of the extraction and transformation of resources and the distribution, use and recovery of goods and materials. Companies take resources from the environment to transform them into products or services. Then, they distribute the products or services to consumers at sale points or to other firms, and the products /services are used by consumers in the marketplace. This is aptly shown in Figure 4.33 (Prieto-Sandoval, 2017).

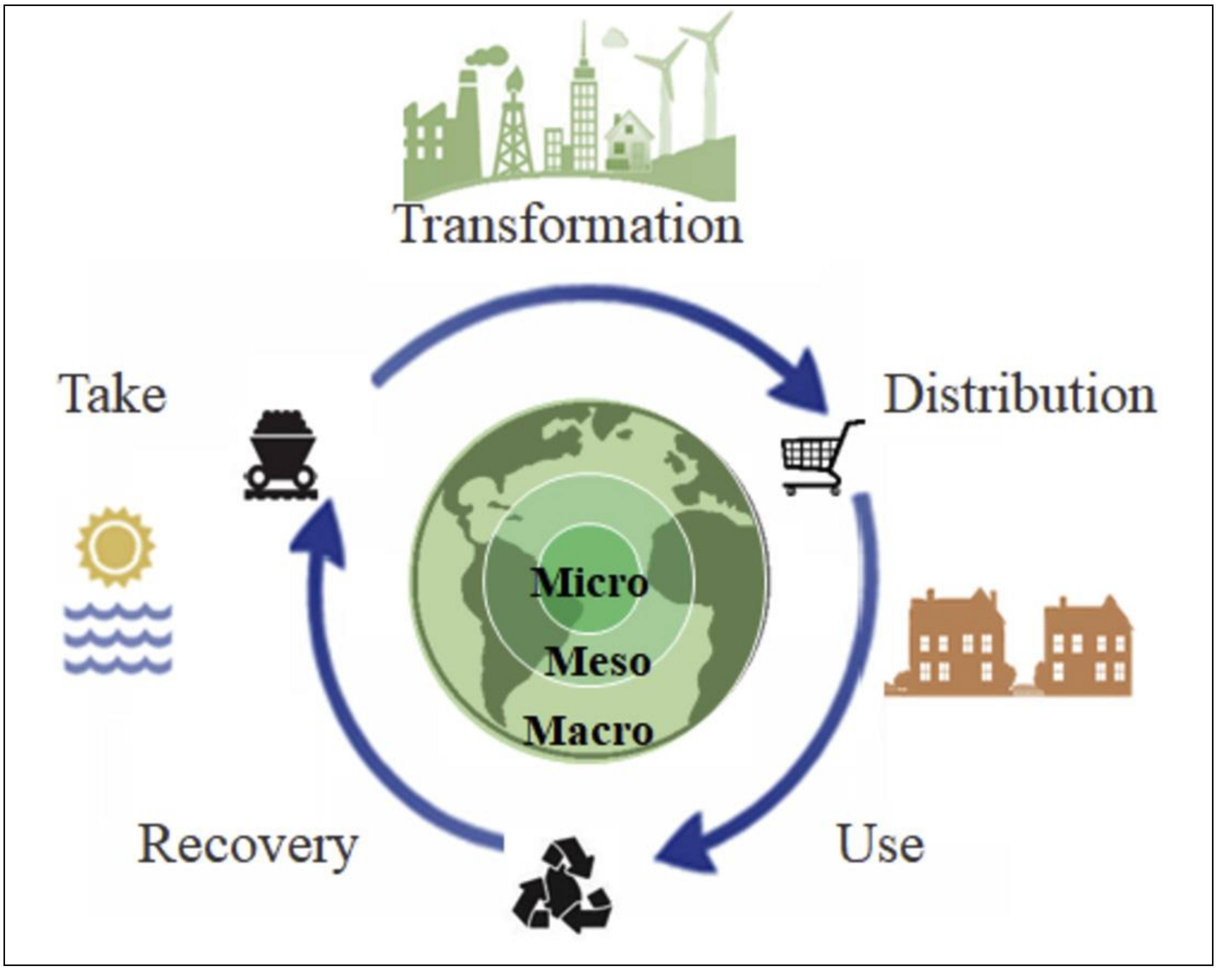


Figure 4.33: The Circular Economy Cycle (Prieto-Sandoval, 2017)

The diversity of the circular economy can be seen in the characterization at three different levels: Micro, Meso and Macro.

At the Micro level: this represents where companies and consumers reside. Companies are focussed on their own improvement processes and eco-innovation development. For the most part industry is based on relatively standard sustainable development processes applied through the linear way of thinking, such as reducing wastes and optimizing resources for cleaner production that lowers its environmental footprint.
At the micro level, the transition towards the circular economy implies the adoption of cleaner production and eco-design. As eco-design considers all the environmental impacts of a product since the earliest stages of design, it has the potential to improve the circular economy approach by favouring the improvement of material and resource use. The introduction of cleaner production provides environmental benefits and economic benefits to companies (Ghisellini, 2015).

At the Meso level: this represents all inter-industries and inter-firm networks. Here reside companies who belong to an industrial symbiosis that will benefit not only the regional economy but also the natural environment. The Meso level uses these interactions among different industries where each benefit from the by-products of one industry as raw materials for its own production and is similar to ecological industry concepts. Results show that in several cases industrial symbiosis and environmental improvement are carried out at Eco-Industrial Parks (EIP) level. The adoption of a lifecycle perspective in the supply chain of the symbiosis carried out by an EIP is important for the correct evaluation of the environmental performances of an EIP (Ghisellini, 2015).

At the Macro level: this represents the highest level where cities, countries and international agencies reside. The focus is on the development of eco-cities, eco-municipalities or eco-provinces through the development of environmental policies and institutional finance (Prieto-Sandoval, 2017). At the macro level, the incentives for the circular economy must be phased in with societal and stakeholder interests.

Elia's research paper reports that the most analysed circular economy field of intervention is the macro level: 56% of analysed studies focus on the assessment of CE strategies at this level, while 25% and 19% look at the meso and micro level, respectively.

Level			**Circular Economy Requirements**				
	Research paper	Methodology	Reducing input and use of Natural Resources	Increasing share of Renewable Resources	Reducing emissions	Reducing valuable material losses	Increasing the value durability of products
Macro	Moriguchi (2007)	STIS	X	X			
	Haas et al. (2015)	STIS	X				
	Geng et al. (2012)	SPIS	X				
	Guo-gang (2011)	SPIS	X	X	X	X	
	Qing et al (2011)	SPIS	X	X	X	X	
	Geng et al. (2009)	SPIS	X			X	
	Zaman and Lehmann (2013)	SPSI		X		X	
	Su et al. (2013)	SPIS	X	X	X	X	
Meso	Li and Su (2012)	SPIS	X		X	X	
	Genovese et al, (2015)	STIS	X	X	X	X	
	Wen and Meng (2015)	SPSI	X			X	

Micro	Ellen MacArthur (2015a)	SPSI	X	X		X	X
	Di Maio and Rem, (2015)	SPSI		X			
	Park and Chertow (2014)	SPSI		X			

Key: STIS – Standardised Indicator Set SPIS – Specific Indicator Set
SPSI – Specific Single Indicator

Table 8: Level analysis about Circular Economy measurement (Elia, et al, 2017)

Table 8: outlines the literature classification based on the ability of each method to measure the five CE requirements in a Micro, Meso and Macro level.

4.2.8 **Digitisation and the Circular Economy**

The intersection between digital technologies and the CE is a meagre but fast-growing area. Digital technologies have come to the forefront in recent times and businesses unable or unwilling to grasp its concepts have been left behind clutching at straws. So far, the growing literature on the CE relies on studies and concepts from adjacent research fields on circular design, industrial ecology and circular procurement, whereas studies on evaluating the application of digital technologies in the context of the CE have been somewhat limited. This section should go a little way to improving this. Data-driven intelligence is rapidly becoming a pervasive feature of our economy, where data gathered through social, mobile, machine and product networks are being leveraged through data analytics to create new forms of value (Charnley, et al, 2019).

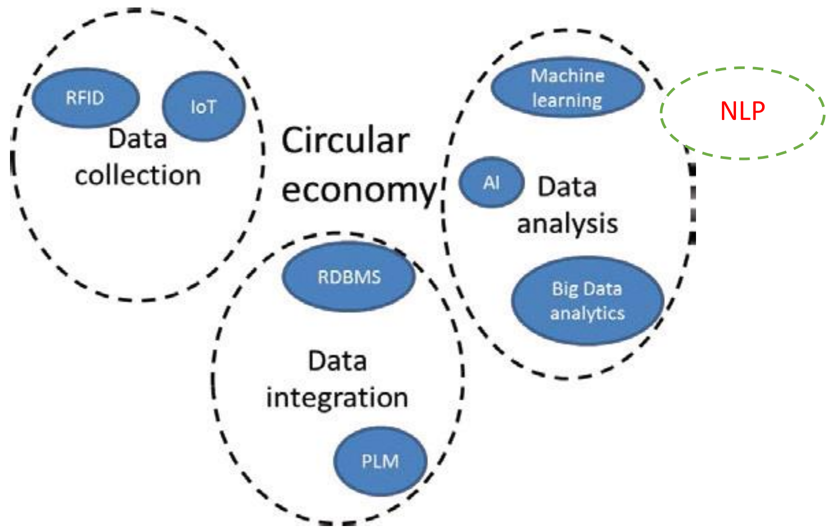


Figure 4.34: Grouping of technologies according to three architectural layers (Pagoropoulos, 2017)

Figure 4.34 represents the grouping of the technologies according to three architectural layers, but NLP is totally new and not originally in the author's diagram but included as a welcome addition to data analysis. The data collection gathers data from RFID and the Internet of Things (IoT), data integration formalises technologies that assist with the transformation and maintenance of data i.e. Relational Database Management Systems (RDBMS) and Product Lifecycle Management (PLM) systems and then data analysis, where these technologies are used for extracting business value for decision making through the analysis of data. Included in data analysis are Machine Learning, AI, Big Data analytics and the new addition of NLP.

4.2.9 Radio Frequency Identification (RFID)

Radio Frequency Identification (RFID) is used in Data Science as a data collection technology. RFID uses electromagnetic fields to automatically identify, and track tags attached to an object. Within the CE, RFID can be used to track material flows to enable value recovery through the implementation of Re-strategies - reuse, repair, recycle and remanufacture (Pagoropoulos, 2017).

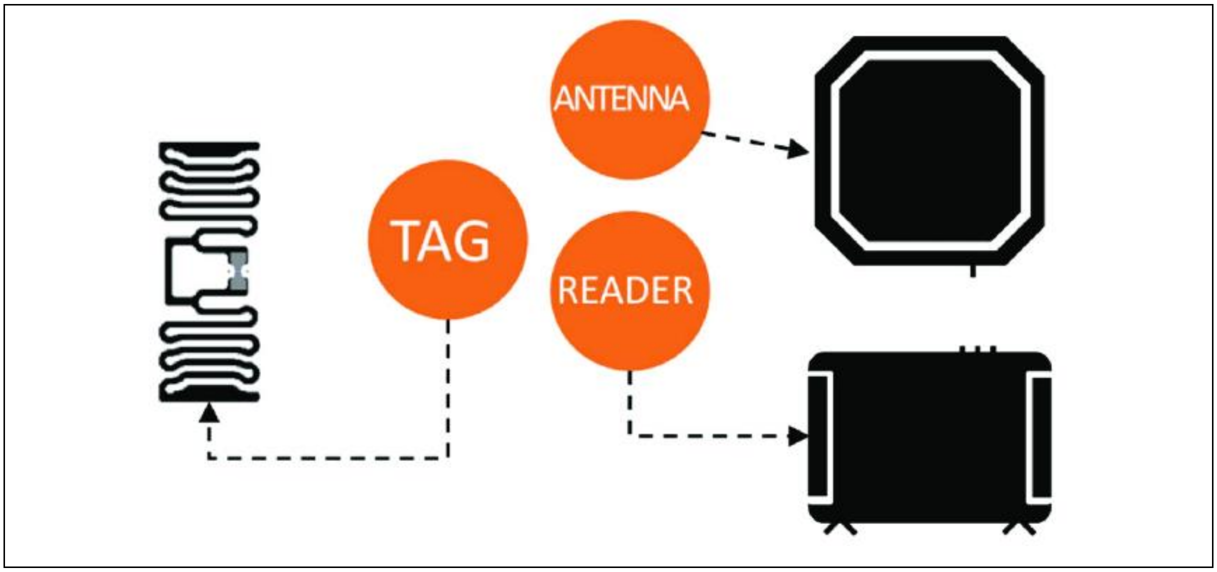


Figure 4.35: Typical Radio Frequency Identification (RFID) system block scheme (Condemi, 2019)

RFID technology is an automated identification system mainly based on the RF microwave transmission and is considered the natural evolution of traditional identification systems, such as barcodes, magnetic cards and smart cards (Condemi, 2019). Within a typical RFID system as in Figure 4.35 above, a computer is used as an input device, a controller with a control module and a radio module uses a microprocessor which is classified whether the antenna is integrated or external. It is reasonable to use a small antenna for short distances and larger antennas for larger distances. The tag contains a dedicated memory with key information about the product or object to be identified, basically the tag contains the identification code. The information (data) is transmitted to the reader that then converts the radio waves into more user-friendly data.

The Benefits of RFID if used wisely are:

- Better distribution of assets
- Real-time visibility of products and materials
- Visibility allows increased operational capability
- Cost reduction due to reduced errors

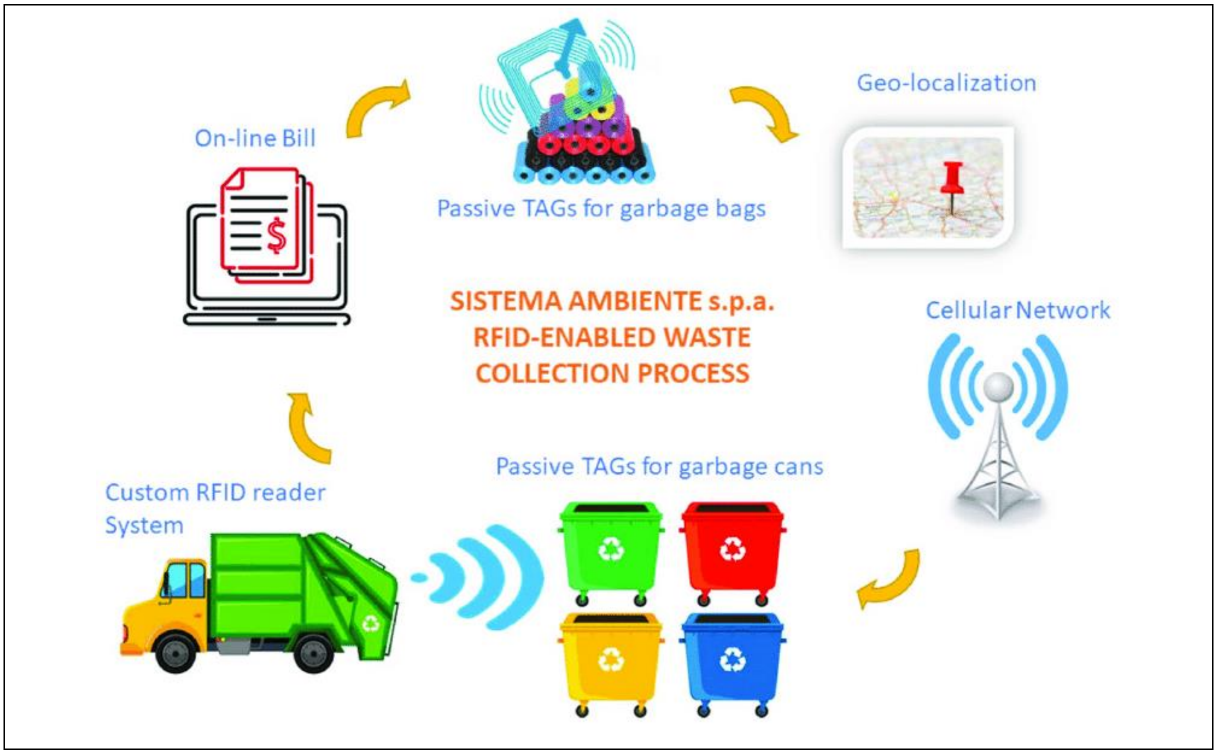


Figure 4.36: The Waste Collection Cycle (source – Sistema Ambiente s.p.a, 2020)

RFID is used in the retail industry to generate thousands more time data collections than was previously collected using barcoding. The Italian company Sistema Ambiente s.p.a. are using RFID in their waste collection business, Figure 4.36 illustrates the process they are using. In Buildings as material banks (BAMB) projects RFID data tag's information is stored within a block chain to track specific tagged materials location and status throughout its lifecycle.

RFID can be used to track and trace products and materials through multiple cycles in its lifetime. This concept is of particular interest when it comes to complying with the REACH regulations and control of hazardous materials or substances of very high concern**.**

For example, RFID tags can be placed in or on products and have important information about the products, products can then be monitored while in use to extend their lifetime by the recovery of components for reuse or remanufacturing and to inform for end-of-life strategies, waste management or recycling. I can see this being of vital importance when you are recycling and re-designing products. Many years ago, when barcoding was being used in manufacturing to pick and assemble parts, it brought welcome relief by removing to an extent the human errors that normally occur and replaced it with the RFID reader and robots that don't make errors. In order to take advantage of this system the RFID tag is imbedded in the component as it returns for recycling the tag information is read, this data already stored can then be added to or for the new product that it is about to become.

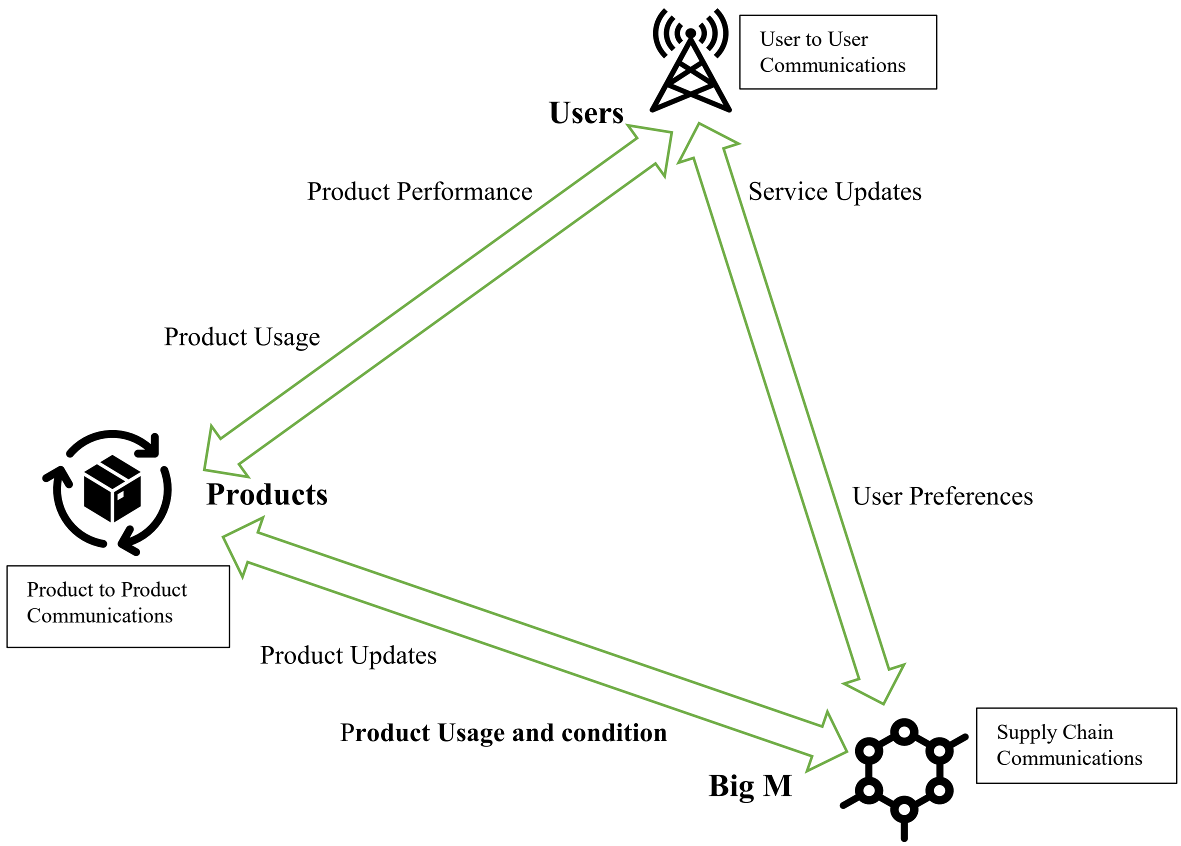


Figure 4.37: Data Flows Enabling Circular Strategies (based on Charnley, et al, 2019)

Although Charnley, uses this diagram in Figure 4.37 to investigate data acquisition and interaction in the remanufacturing process between the users, products, the manufacturer (Big M) and the supply chain, this could similarly be used in the example above with the RFID tags. The full variety of data can be collected from these data flows and categorised into structured, semi-structured and unstructured data referred to in Figure 3.5: Types of Data. Data obtained from the RFID tags in the products will be critical to the product's quality assurance.

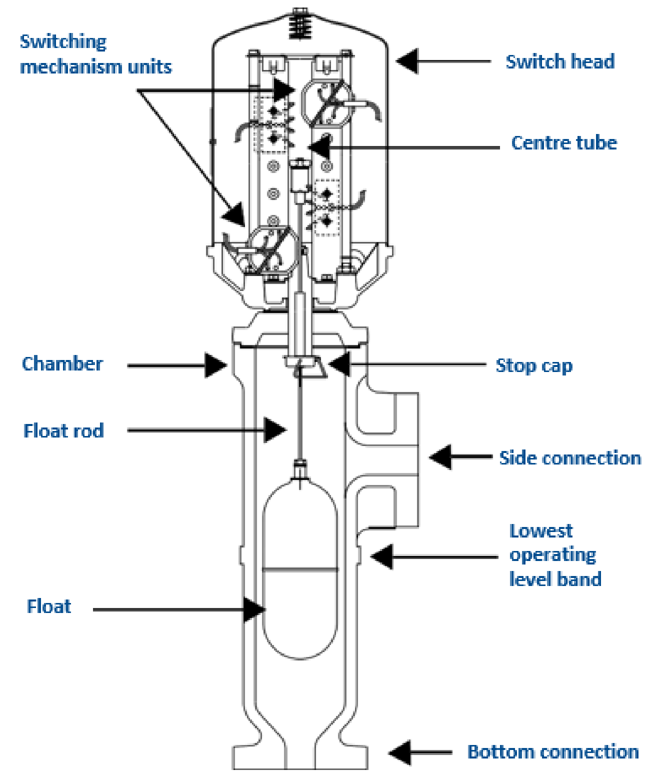


Figure 4.38: Boiler Level Control

To further expand this example, original data has been gathered from an assembled Delta Mobrey boiler water level control shown in Figure 4.38 above. This controller is designed to regulate the flow of feed water into the boiler in proportion to the steam demand by using the change in boiler water level as a load indicator. All the articles for the product are purchased outside the company and assembled in the factory. Each article can be fitted with a RFID tag (not currently in operation) which displays data on its unique part number/s, description, materials, storage, product associations, and any special conditions. The RFID tag can be an all-in-one unit consisting of antenna, evaluation and CANopen interface. The RFID tag can offer high protection for use in harsh environments, be used in hot and cold temperature ranges, withstand high shock and vibration resistance and is suitable for mobile applications. The RFID tags are the information carriers with integral transponders. This allows an article to be traced for its material composition but also provides vital information for adaptation to the CE. The RFID system can be used to check whether the product has the correct material in the required quantity and in the correct places, all critical considerations for REACH compliance.

Product Description	**Part Number**	**Description**	**Sub-Assembly**	**Material**
Boiler Water Level Controls - Steam	81006	Modulating Head & Chamber CI		Cast Iron
	M904/0		Kit COM Parts MOD Control HD	
	M885		Head Assy Inductive	
	H1767		Base, VAB Switch, NEMA4	Aluminium Alloy (Chromate Phosphate)
	H3631		Terminal Block, 2 way, Porcelain	Porcelain and brass
	9922-806		Screw 6BA, SL CH HD, STL ZP	Steel, Zinc Plated
	9926-833		Washer 6BA SH/Proof INT STL ZP	Steel, Zinc Plated
	9925-838		Nut 6BA Full Steel ZP	Steel, Zinc Plated
	M882		Plug, Conduit, Brass Hex HD	Brass
	M667		Coil, Long with M666	
	M844		Coil, Assy, Modulating Head F/I	Silicone bonded, glass cloth

	9982-001		Solder, 16SWG Type HMP 500GM	
	M666		Wire Strip Detail - Red	
	G1648		Eyelet, Multi-purpose M25070	
	H3070		Cover, Vert Switch NEMA4	Carbon steel
	H1554/UP		Cover Shell, Vert NEMA4 250 CS	Mild Steel Zinc plated
	BML207-E52		Kit, Paint, Matt Black	
	M887		Tube-Cover Assy	
	H1582		Endcap, Boiler Steam Tube	Stainless Steel
	M819		Tube, Pressure Inductive Head	Stainless Steel
	H1573		Flange, Cover, VAB	Stainless Steel
	H1549		Washer, M6 Vistop	Stainless Steel
	9721-823		Screw M6, Hex HD, STL ZP	Stainless, Zinc Plated
	M652		Plate Support	Stainless Steel
	I1554		Circlip	Stainless Steel
	M889		Pillar, Switch, IND, HD	Stainless Steel
	9725-516		Nut, M8, Thin, SS	Stainless Steel
	H3366		Gasket, NON ASB	Silicone

	9726-817		Washer, M8 SH/PROOF INT ST ZP	Stainless, Zinc Plated
	M834		Rod, Tie	Aluminium
	9725-802		Nut M3 Full Steel ZP	Stainless, Zinc Plated
	9726-831		Washer, M3 SH/PROOF INT ST ZP	Stainless, Zinc Plated
	9726-807		Washer M3 Plain Form A STL ZP	Stainless, Zinc Plated
	H2589		Gasket, Silicone, VAB, Boiler Control	Silicone
	H1545		Gasket, Silicone, VAB, Switch	Silicone
	9722-601		Screw M5X30 HEX HD SS	Stainless Steel
	9926-416		Washer 6BA Small Brass DNP	Brass
	9726-551		Washer, M5 Spring, Single B SS	Stainless Steel
	G1697		Tape, PTFE 1/2" Wide, 12M	PTFE
	M901		Flange Spacer	Stainless Steel
	U59		Bar Al Alloy Dia 2.375" 6082-T6	Aluminium Alloy
	G4696		Gasket, Non ASB	Silicone

	M956		Nameplate, Modulating Control	Aluminium Alloy
	I1893		Pop Rivet	Aluminium Alloy
	G4688		Label (Name), Warning "Remove Tape"	Paper
	M905/U		Kit Unique Parts 81006	
	8231		Chamber, VAB 13KG S,B	Cast Iron
	8231/C		Casting, Chamber, CI	Cast Iron
	9724-847		Stud M12 X 47 Overall Length MB7	Steel
	9724-833		Stud M12 X 48 Overall Length MB7	Steel
	M661		Float Assy Modulator	
	9726-510		Washer, M6 Spring Single B, SS	Stainless Steel
	H315		Float, VAB Monel	Monel
	H1474		Shell Half, Closed NA13	Monel
	H1476		Ring, Support, Monel	Monel

	H1475		Shell Half, Open End NA13	Monel
	H416		Adaptor, Float, Monel, VAB Units	Monel
	89005/949		Shell Half, Open End Heat Treated	Monel
	89005/950		Shell Half, Closed Heat Treated	Monel
	M660		Rod Assy Modulator 443 LG	
	M654		Cap	Stainless Steel
	M659		Core, Modulator	Stainless Steel
	H1584		Collar, Retaining, ST/ST	Stainless Steel
	H331		Stop-cap & Retaining Clip Assy	Stainless Steel
	H335		Screw, Float Attachment	Stainless Steel
	M664		Rod, Float	Stainless Steel
	M802		Spacer	Stainless Steel
	9725-818		Nut, M12 Full Steel ZP	Steel
	G302		Label Warning Boiler Control	Paper
	9923-493		Screw, Drive No2 RH, Steel	Steel
	H3677		Label (Name) VAB "Untie" 80163	Stainless Steel

	G5081		Tag Number Plate, SPC95	Stainless Steel
	Colour Key:	Sub-Assembly		
		Sub-Assembly (Level 2)		
		Sub-Assembly (Level 3)		
		Sub-Assembly (Level 4)		

Table 9: Original Product Data

Table 9 represents a basic format for a complex database, after all the variations are added and the product associations are realised. With the RFID tag in place the articles can be traced through their product life cycle and continue to be traced if they are reused, recycled, refurbished etc in accordance with Figure 4.31 on Ripanti's reverse logistics. The difficulty is finding out what material the articles are made off especially if they are complex articles. But once the material is known then checks can be made against the REACH SVHC list to eliminate the use of any hazardous substances. In this original data H1767 contains the SVHC chromate phosphate (highlighted in red). This is very important because many organisations are unable to do this, and it can be all outlined in a concentric way in a Standard but now this standard does not exist but is very needed.

4.3 Is there any conflict between the Financial Economy and the Circular Economy?

4.3.1 **Introduction**

The Circular Economy aims to separate economic growth from continuous use of resources by using resources more efficiently. Products are designed eco-friendly and built to be part of a network where they will be used extensively, then depending on their characteristics, they can be reused, refurbished, upgraded or recycled. The more effective use of products, components and materials is expected to lead to more value appreciation, both through cost savings, eco-design and by developing new markets or expanding existing ones. Significant environmental benefits are expected to be achieved as shown in earlier chapters by reducing the use of resources, (i.e., water and energy) and minimizing waste output and the use of landfill sites. These contribute to how we perceive the financial economy impacts the circular economy.

This chapter will seek literary outcomes of whether there is conflict between the Financial and the Circular Economy. Transitioning to a Circular Economy will cost money and lots of it but is there evidence to suggest that finances pose a hinderance to this transition? Will the benefits of the Circular Economy provide the payback for the Financial Economy to invest? These are some of the questions this chapter will look to address.

Whenever there is an environmental disaster there is always a financial cost to it. For example, flooding affects all of us, the UK government estimate that there is over £200 billion pounds worth of assets at risk around British rivers and coasts and in towns and cities, with additional costs in disruption to transportation and energy services (electricity and gas supplies).

4.3.2 **The Financial Economy**

The Financial Economy is a fairly new concept that includes the part of the economy which stems from the financial industry. The growth of the financial economy depends on the interactions of the financial elements in the financial processes and products.

In early 2017, the Circular Economy Finance Support Platform (CEFSP) was formed as a joint initiative of the European Commission and the European Investment Bank (EIB) to promote the coordination and knowledge exchange amongst key CE stakeholders and implement concrete actions needed to enhance investments in the CE.

To accelerate the transition to a Circular Economy, it is necessary to invest in innovation and to provide support for adapting the industrial base. Over the 2016-2020 period, the European Commission has stepped up efforts in both directions totalling more than €10 billion in public funding to the transition. This includes:

- €1.4 billion from Horizon 2020 until 2018 (on areas such as sustainable process industries, waste and resource management, closed loop manufacturing systems or the circular bioeconomy), among which €350 million are allocated to making plastics circular.
- At least €7.1 billion from Cohesion Policy (€1.8 billion for uptake of eco-innovative technologies among SMEs and €5.3 billion to support the implementation of the EU waste legislation).
- €2.1 billion through financing facilities such as the European Fund for Strategic Investments and InnovFin.
- At least €100 million invested through LIFE in more than 80 projects contributing to a circular economy.

(EC, 2019)

The transition of a country to the CE entails significant costs but also creates important benefits related to resource usage, environment, economy and society. This has led many developed countries to develop early transition policies and strategies supported by appropriate financial programs. All aspects of finance are essential to the CE.

InnovFin – the EU Finance for Innovators programme was launched in 2014 by the European Commission and the EIB Group, with the purpose to offer a new generation of financial instruments and advisory services to help innovative firms access finance more easily across Europe and beyond. They have financed some truly ground-breaking inventions to the tune of Euro 14 billion so far. More than 110 projects and over 11,000 small and early-stage enterprises have benefitted from small tech start-ups to large facilities and CE companies (EIB, 2020). The EIB supports and protects the natural environment and human well-being by supporting the CE and waste management to keep materials and resources in circulation, minimising waste and reducing carbon emissions. InnovFin promotes a range of tailored debt and equity products from guarantees for intermediaries that lend money to SMEs to direct loans to enterprises.

In general, regulations can have a positive impact on growth by removing certain market failures with a view to improving economic efficiency. But regulations can also have a negative impact on growth by creating substantial compliance costs, undesirable market distortions or unintended consequences. The compound impact of regulation on growth depends on which effect is larger and this can vary enormously depending on contributory circumstances. The complexity of this then becomes apparent when you add the ever-changing mountain of European environmental regulations.

The National Consumer Federation's (NCF) researched report in response to questions being asked by the Competition and Markets Authority (CMA) on consumer priorities for 2015/16 has produced a chart (shown below) showing the UK regulatory burden on business. The key figure for the purposes of this report is that of: Recycling and Environmental regulations is 26% of the total regulatory burden on UK businesses. Calculating this into a monetary value using the £10.75 billion figure reported as the total regulatory burden. Then Recycling and Environmental regulatory burden is £2.795 billion, a huge amount based on 2008 figures (CEBR, 2015).

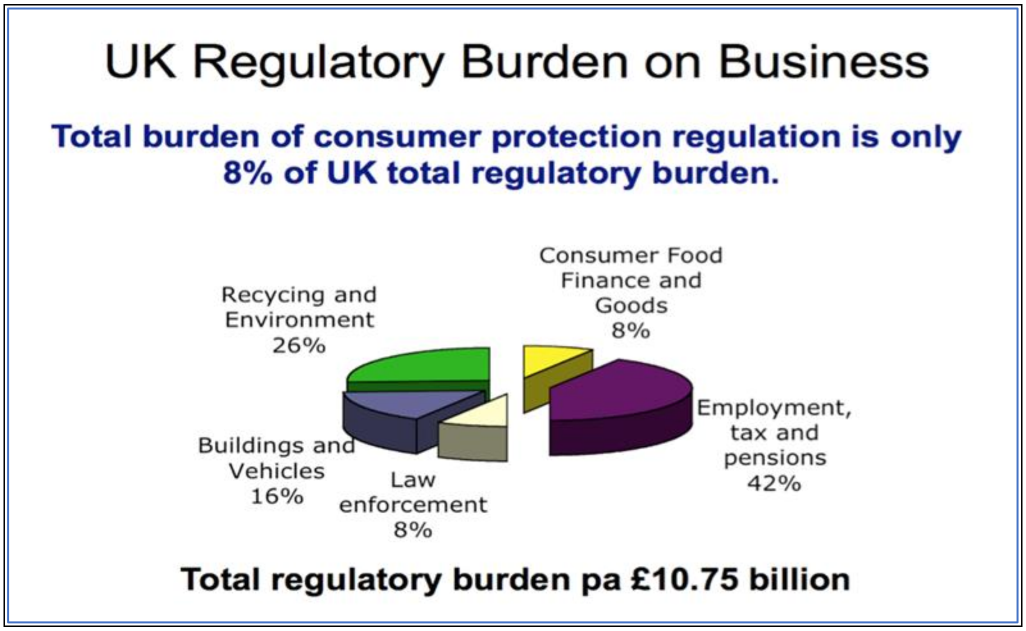


Figure 4.39: Environmental Regulation: Impacts on UK Businesses (CEBR, 2015)

Note: The above analysis was undertaken for the NCF adopted paper "A fuller picture".

It is so important in REACH that the financial resources needed for REACH implementation is in place. The Commission has conducted an extended impact assessment on REACH. Macroeconomic effects in terms of Gross Domestic Product (GDP) are expected to be limited, and REACH is expected to yield business benefits including improvements in innovation, competitiveness, and workers safety, as well as significant health cost savings. The costs of registration, including the necessary testing, are estimated at EUR 2.3 billion over the eleven years it will take to register all the substances covered by REACH. The total costs, including those to downstream users, are estimated at EUR 2.8 billion to EUR 5.2 billion, depending on the extent to which registration costs will increase prices of chemicals and on the costs of substituting chemicals that will be withdrawn (an estimated 1.2%). If REACH succeeds in reducing chemical-related diseases by only 10%, the health benefits are estimated a EUR 50 billion over 30 years (EC REACH, 2006).

The recycling of e-waste has already been mentioned but the increased demand for rare earth metals found in WEEE cannot be overlooked because of the high costs involved and the potential for use of innovative technologies.

Closed cycle management as practised in Germany, is not only contributing to the environmental protection, but it also pays off economically. The waste management industry has become an extensive and powerful economic sector in Germany, almost 200,000 people are employed in approximately 3,000 companies which generate an annual turnover of approximately 40 billion euro (Nelles, 2016).

The Netherlands Organisation for Applied Scientific Research (TNO) has made an initial estimate of the benefits that a circular economy would bring to the Netherlands. Among other things, it states that each year, within the sectors involved in the Circular Economy, an extra turnover of 7.3 billion euro can be generated, which will account for 54,000 jobs in the Netherlands. The use of raw materials can be reduced by approximately 100,000 kilotons. In an exploratory scenario study, the Rabobank has estimated that a CE can lead to extra growth in GDP ranging from 1.5 billion euros in a business-as-usual scenario to 8.4 billion euros in the most circular economic scenario (Ministry of Infrastructure and the Environment, 2016). The world economy is $72 trillion Australian dollars in size but applying the Circular Economy model would lead to at least $1 trillion in savings immediately and potentially much more in years to come according to McKinsey & Co (Benn, 2014). The economic motivation for transitioning to the Circular Economy is very significant because according to research done by Ellen Macarthur Foundation, the net material cost savings at a global level determined by the adoption of the Circular Economy measures may exceed 1 trillion US dollars annually by 2025 (Bonciu, 2014).

In the Ellen Macarthur report, substantial net material savings based on detailed product-level modelling, the foundations, first circular economy report estimated that in the medium-lived complex products industries, the circular economy represents a net material costs savings of opportunity of US$ 340 TO 380 billion pa at an EU level for a transition scenario and US$520 TO 630 billion pa for an advanced scenario, net of the materials used in reverse-cycle activities in both cases (EMF1, 2015). The difference between this estimate and the Bonciu one is the inclusion of future years up to 2025. The European Commission is also proposing to encourage better product design by differentiating the financial contribution paid by producers under extended producer responsibility schemes based on the end-of-life costs of their products. This should create a direct economic incentive to design products that can be more easily recycled or reused.

Further afield in Canada, circular procurement is progressing, it is estimated that Organisation for Economic Co-operation and Development (OECD) countries spend 12%

of their GDP on public procurement. With a $1.9trillion GDP, Canada spends $230billion on procurement alone, and Ontario spends $89 billion. By leveraging purchasing power to drive sustainability we can hasten the transition to an effective Circular Economy (Recycling Council of Ontario, 2020).

Standardization, for the purposes of expressing the findings in monetary terms, assumes that the estimated impact is constant over time, standardization at the UK level would be associated with approximately £8.2billion of the £29.0 billion of GDP growth recorded in 2013, based on 2014 prices, (Cebr, 2015).

4.3.2.1 **Examples of Circular Economy Funding**

Horizon 2020 is the financial instrument implementing the "Innovation Union" initiative aimed at securing Europe's global competitiveness. It is the biggest EU Research and Innovation programme ever with nearly 80 billion Euro of funding available.

1. R2π – tRansition from linear 2 circular: Policy and Innovation is a three-year project within the environment theme of Horizon 2020. The project began in November 2016 and was due to end in October 2019 with a total funding of 3 million euros. The aim of the R2π project is to highlight sustainable business models for CE and to propose policy packages that will support such business models (r2piproject, 2020).

2. The Irish Minister for communications, Climate Action and the Environment has launched a 600.000 EUR funding opportunity for novel approaches to promote the CE, maximise resource efficiency and reduce waste. This green enterprise CE funding programme will provide grant aid to demonstrate type projects in the following thematic areas:

Food waste prevention

Construction and demolition waste

Plastics

Resources and raw materials

3. Zero Waste Scotland through its CE Investment Fund are investing £18 million pounds as grant funding to small and medium enterprises who are helping to create a more CE. They are looking for innovative projects with the ability to deliver carbon savings, leverage

investment and create employment. Zero Waste Scotland is a lighthouse for the CE and are happy to both fund and support businesses who are willing to progress CE opportunities to tackle the global climate risk emergency.

4. The Circular Economy Centre (CEC) is part of a consortium at the University of Cambridge that was awarded more than £1 million funding by the UK Research and Innovation agency to look at “Circular Economy Approaches to Eliminate Plastic Waste”. The project will work on innovative alternatives to plastics and novel technologies for the utilisation of waste plastics.

5. Sadako Technologies is a Spanish company setup out of the concerns of its founders to use technology and engineering to build a better world. Sadako are specialists in the development of the latest generation AI and Robotics technologies. They use these technologies and apply them to the recycling field. In 2017, they received funding from the Horizon2020 program to develop a waste stream monitoring system based on AI technology, the project was called Rubsee. The project successfully ended in 2019, with two main outcomes: relevant advances in Sadako’s AI technology for waste detection and 3 pilot systems installed and running in three European waste treatment plants (Sadako, 2020).

4.3.3 **The Circular Economy**

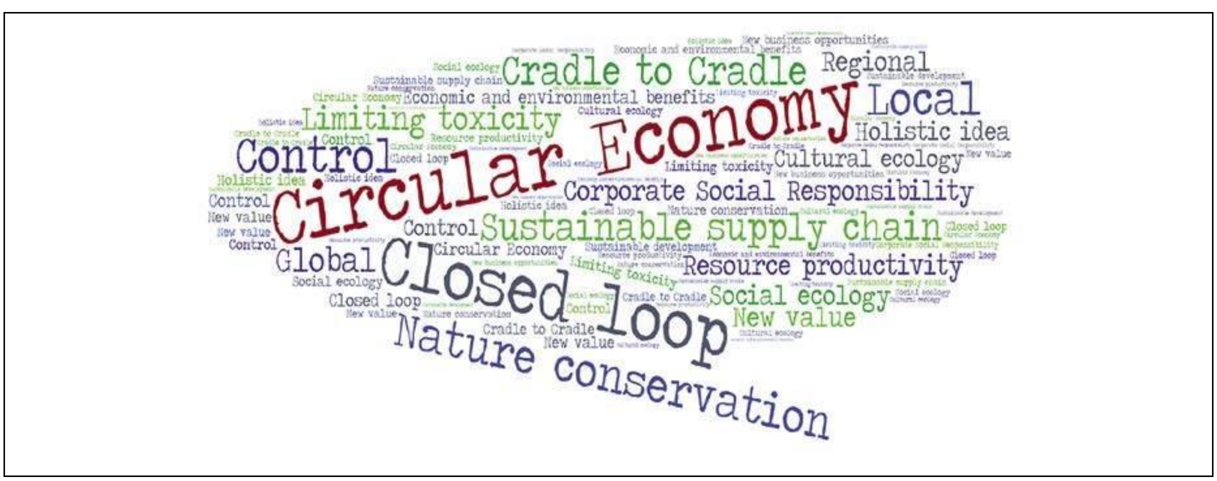


Figure 4.40: Word Cloud of Circular Economy (Turon, et al, 2016)

The word cloud in Figure 4.40 was created by Turon, et al based-on references from Benton, Hazell and Hill (2015); Gallaud and Laper-che (2016); Krarup, Kiorboe and Sramkova (2015) and Weetman (2016). However, nothing more was said about the word cloud, but given the fact that the word cloud is a visual representation of the text used, some of the prominent words or concepts become quite interesting. For example, sustainable supply chain, corporate social responsibility or nature conservation. These are all big topics that could be researched as contributing factors in a CE but not covered by this thesis. The CE allows the creation of fully sustainable supply chains. This strengthens the argument on how diverse the CE is and how the standards development process is ideal for collaborating the data on the CE.

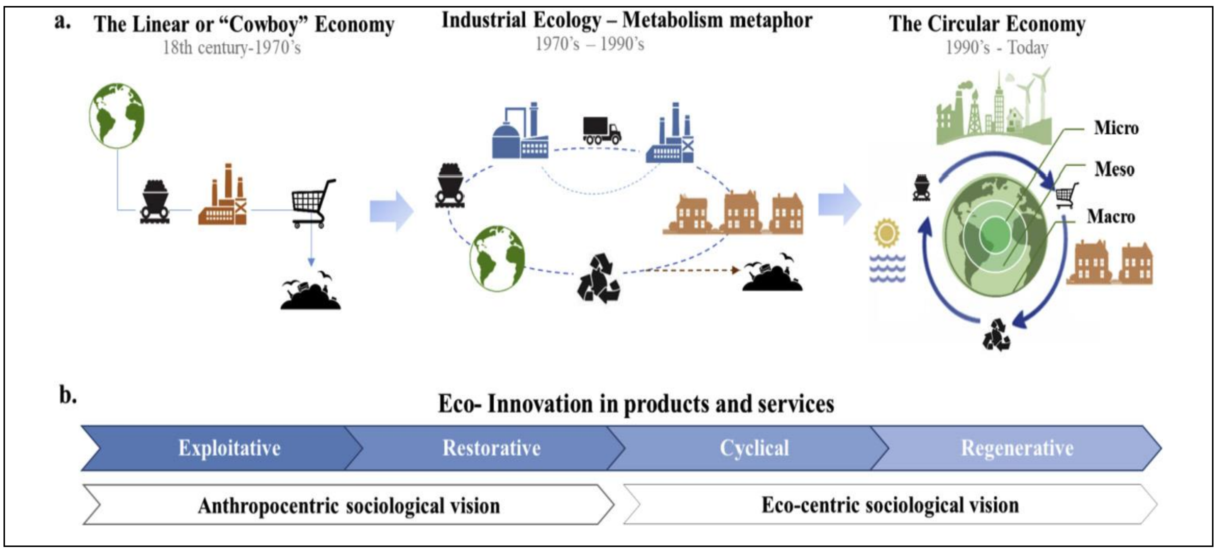


Figure 4.41: Circular Economy Knowledge Map (Prieto-Sandoval, et al, 2017).

The Circular Economy replaces the current Linear Model of take raw materials – make products – dispose of them (referred to in the Introduction). Too often we throw away valuable resources in this "Linear Model", so without change this can only get worse. Figure 4.41 illustrates the path needed to arrive at the CE, divided into three stages:

1. *The Linear Economy* – began in the 18th century to the 1970's, with the industrial revolution and over extraction and exploitation of resources.
2. *The Industrial Ecology* – from the 1970's to the 1990's. In this stage interest for a greener economy surfaced.

3. *The Circular Economy* – from 1990's to today. An addition to the surfaced greener economy to initially explain the feasibility of taking account of environmental awareness in economic flows by closing industrial loops. This stage continues to evolve and expand.

The CE addresses these unnecessary resource losses. How does it do that? More recycling is part of it, but the CE involves much more. It is a model of industrial production which involves designing products so they last longer, so they can be repaired and upgraded, so they can be reused or resold (on eBay, for example), and so their materials can be used in remanufacture (Benn, 2014).

The Circular Economy model (also referred to in the Introduction) promotes the resiliency of 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 CE may seek to extend the useful life of the product, i.e., delay its end of use. It favours the possibility of repair, refurbishment, and reuse before their actual end of life, when it will be recycled into materials that become raw resources. The CE model aims to emulate processes like those that occur in natural environments, where little is wasted, and most is recuperated by another species (Sauve, et al, 2015).

The Circular Economy as defined by the WEF is "an industrial system that is restorative or regenerative by intention and design", (WEF, 2019).

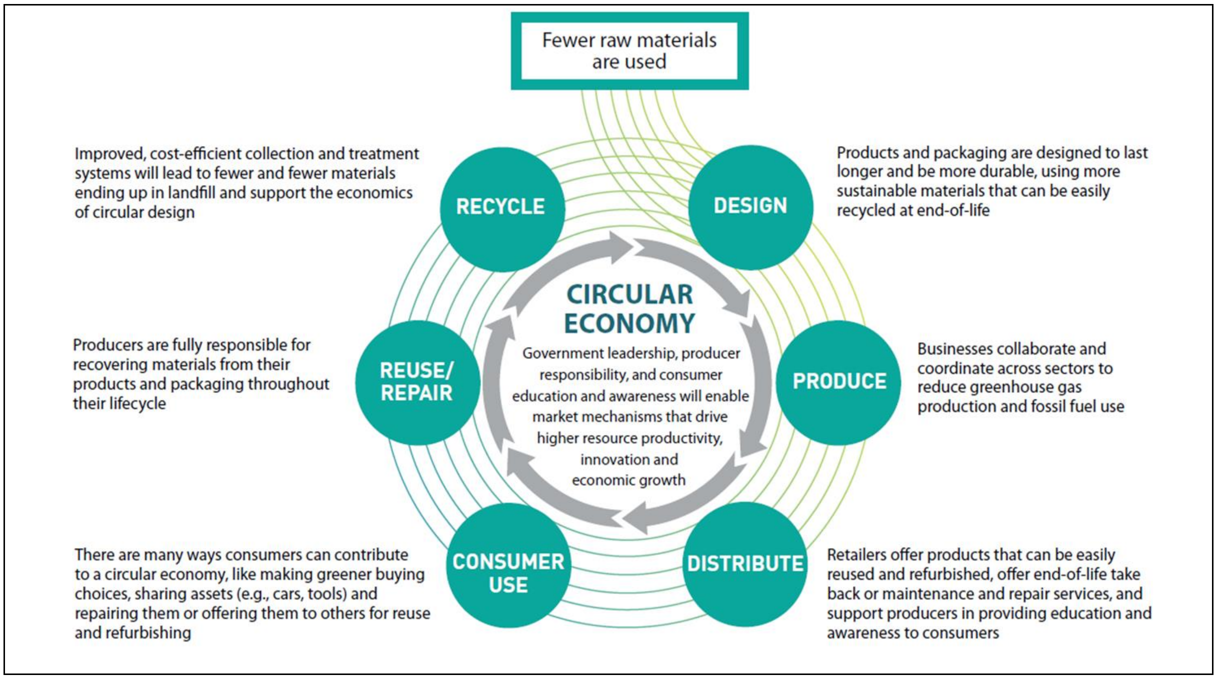


Figure 4.42: The Circular Economy

(Source: Recycling Council of Ontario, 2020)

It is essential when considering the CE of Figure 4.42 to distinguish between social benefit, business and commercial benefit and the effects on economic growth and jobs. These three aspects are far from being logically correlated (Stegman, 2015). The EU will continue to lead the way to a CE and use its influence, expertise and financial resources to implement the Sustainable Development goals. The Action Plan aims to ensure that the CE targets people groups, regions and cities, tackles the environment by fully contributing to climate neutrality but also looking forward to furthering research, innovation and digitalisation.

4.3.3.1 **Seven Pillars of The Circular Economy**

1. *Materials are cycled at continuous high value*: this is very important because some products, when not used, can be very difficult to remove, such as washing machines, tires, mattresses and countless others. Businesses that need to do real Circular Economy must think that after the consumer stops using the product, then the product should be turned into something else, rather than scrap it.

2. *All energy is based on renewable sources*: energy is an important resource in the production of goods, so thinking systems are not just thinking about how to recycle. It must

be thought that one can think of a system that uses energy or uses less energy. What is to be avoided is the movement of energy into production because it means the loss of energy in transportation, by finding a way to use energy in the local area to benefit.

3. *Biodiversity is supported and enhanced through all human activities*: circular Economy must make biodiversity. It is not that the production system is very good. Produce Green products, but some species must be extinct.

4. *Human society and culture are preserved*: in order to produce local labor, the business must also preserve the culture and beliefs of the local people, not come and change everything arbitrarily. Although it may be good in the eyes of the general public, but it may not be the word for the local people.

5.*The health and wellbeing of humans and other species is supported*: the release of toxins and waste that harms nature and organisms is strictly prohibited. If it must be collected and eliminated in a way that does not damage the chain.

6. *Human activities generate value in measures beyond just financial*: businesses with numbers are consistent, but in creating the Circular Economy it is not possible to measure everything by numbers. Some values, such as religious beliefs, the feelings of the employees, are also important.

7. *The economic system is inherently adaptable and resilient*: The Circular Economy can be seen as a very complex process, and if one or more of the failures fails, there must be other means to keep the system running

The Seven Pillars of The Circular Economy is based on research by Antoniou Zabaniotou.

4.3.3.2 **The Circular Economy Principles**

Like the definitions for the CE, the CE principles are shared among the front runners of this concept and each one has a slightly different take on the principles. In the Appendix there is a list of CE principles from different sources, below is highlighted two of these sources.

The Ellen MacArthur Foundation, list only three principles:

1. Design out pollution and waste from your system
2. Keep material and products in use at optimal levels

3. Build and restore natural capital and regenerate natural systems

The Dutch company Circle Economy have aligned their six principles seen in Figure 4.43 to the six steps portrayed in the CE model. For them (i.e., Circle Economy) the circular economy is all about closing resource loops to mimic natural eco-systems in the way we organise our society and businesses (Circle Economy, 2019).

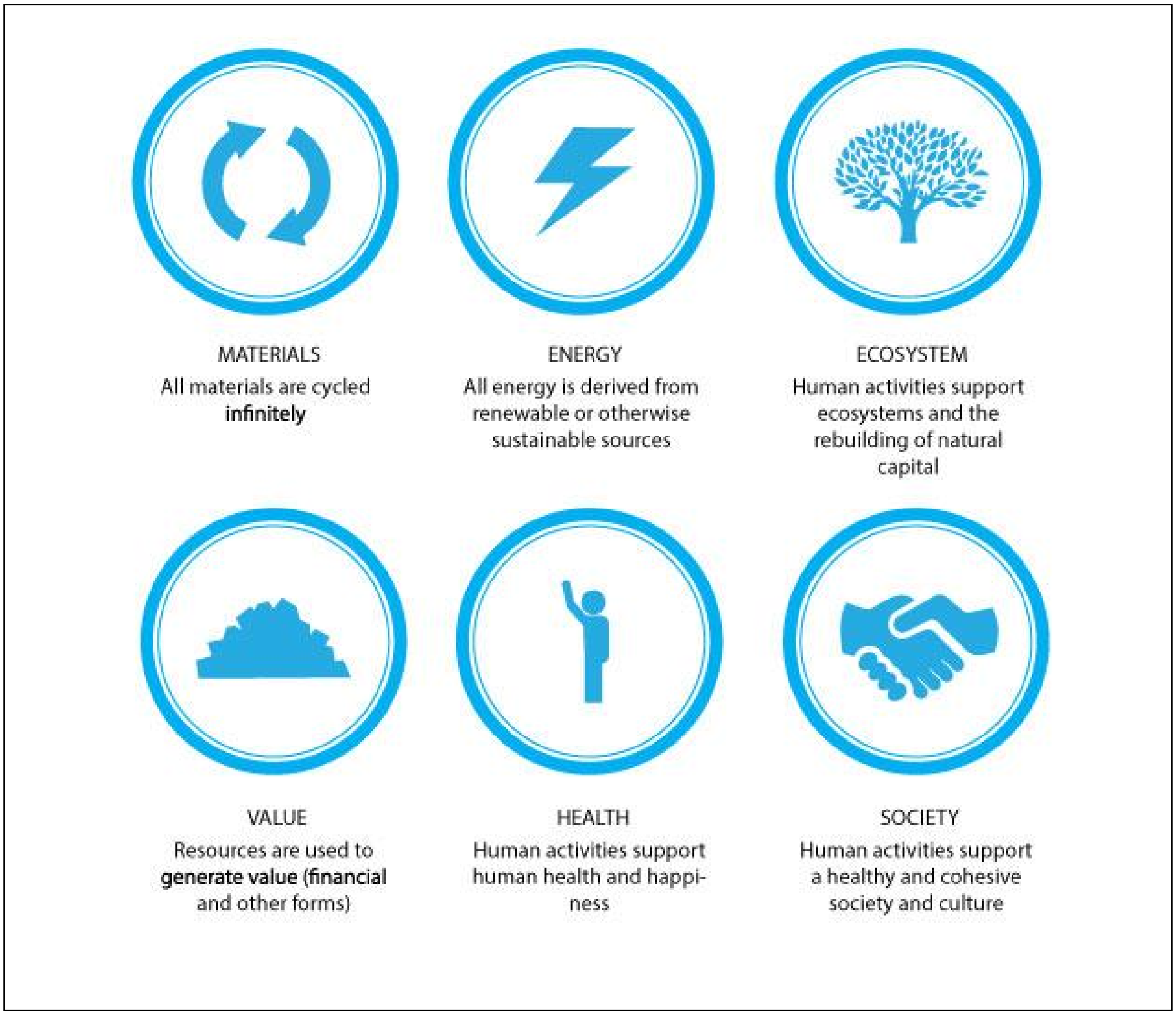


Figure 4.43: The Circle Economy Six Principles (Circle Economy, 2019)

The Circular Economy requires life cycle systems thinking to successfully implement, so therefore it includes many processes or operations from an equally large number of sectors of activity.

The SolarImpulse Foundation have seven principles of production and consumption for the Circular Economy. These are:

1. Sustainable procurement: development and implementation of a responsible purchasing policy
2. Eco-design: process of reducing the environmental impacts of a product or service throughout its lifecycle
3. Industrial and territorial ecology: search for eco-industrial synergies at the scale of a business area – the waste of one company can become the resources of another one
4. Economics of functionality: collaborative economy that favours use over possession and thus tends to sell services related to products rather than the products themselves
5. Responsible consumption and choice of products according social and ecological criteria
6. Extending the duration of use: through repair, reuse and repurpose
7. Recycling: treatment and recovery of materials contained in collected waste

(Piccard, 2020)

The Circular Economy as referred to many times in this report is based on re-using, repairing, refurbishing and recycling our existing materials and products. The vision is to extend the life of resources for as long as possible because we are running out of these resources. In a CE, materials that can be recycled are re-introduced back into the economy as new raw materials thus revitalising the initial supply chain. These recycled raw materials can be referred to as “secondary raw materials” and can be traded and shipped just like primary raw materials from traditional extracted sources. Currently, secondary raw materials only account for a very small proportion of the materials used in the EU. Highly, recommended are waste management practices for “secondary raw materials” because they have a direct impact on the quality and quantity of the materials and so improving or maintaining a high standard of these practices is essential.

4.3.3.3 **Circular Economy Recycling**

In the past regulation on recycling was scarce and in some countries like the United States e-waste recycling was left to the individual State to deal with which meant e-waste was being disposed of with the normal household recycling and thus sent to landfill. Recycling is better for the environment than landfilling our waste and even better, is to first reduce the number of products we consume and reuse what we already have. In Europe, the European Commission's launched the Circular Plastics Alliance (CPA) back in 2018, to help accelerate the transition towards the CE. The CPA will consist of key industry stakeholders collaborating across the full plastics value chain to reduce plastics littering, increase the share of recycled plastics and stimulate market innovation. The alliance will aim to improve the economics and quality of plastics recycling in Europe.

Recycling is mainly seen as a good thing, but it has its critics, one of the barriers faced by manufacturers who want to use secondary raw materials is the assurance of their quality. Standards would go a long way to providing some consistent quality in recycling, in its absence ascertaining impurity levels or the suitability of secondary raw materials becomes difficult. You could develop Standards for recycling with a requirement for the manufacturer to supply the customer with a material certificate (if requested), showing both the chemical and mechanical composition of the secondary raw material supplied, like EN 10204:2004 – 3.1 mill certificates.

The recycling rates and use of recycled materials in the European Union are steadily increasing. Overall, the EU recycled approximately 55% of all waste excluding major mineral waste in 2016, compared with 53% in 2010. The more important recycled waste streams here are packaging waste at 67% in 2016, compared with 64% in 2010 and in particular plastic packaging waste at 42% in 2016, compared with 24% in 2010. The waste of WEEE, such as computers, televisions, fridges and mobile phones, which include valuable materials which can be recovered (e-waste) in the EU reached 41% in 2016, compared with 28% in 2010 (Eurostat, 2016). We know that electronic waste i.e., computers, televisions, fridges, and mobile phones have become one of the fastest growing waste streams in the EU. But despite huge efforts by the EU to encourage recycling some countries have been rather slow on the uptake. On the other hand, some European countries are keenly promoting and recycling their e-waste, noticeably the Scandinavians have some of the highest recycling rates. The collection of recyclable waste is well established in Germany. There are always some problems to improve the quality of recovery. The proportion of recycling needs to be further increased, too many waste streams are still being incinerated instead of being recycled.

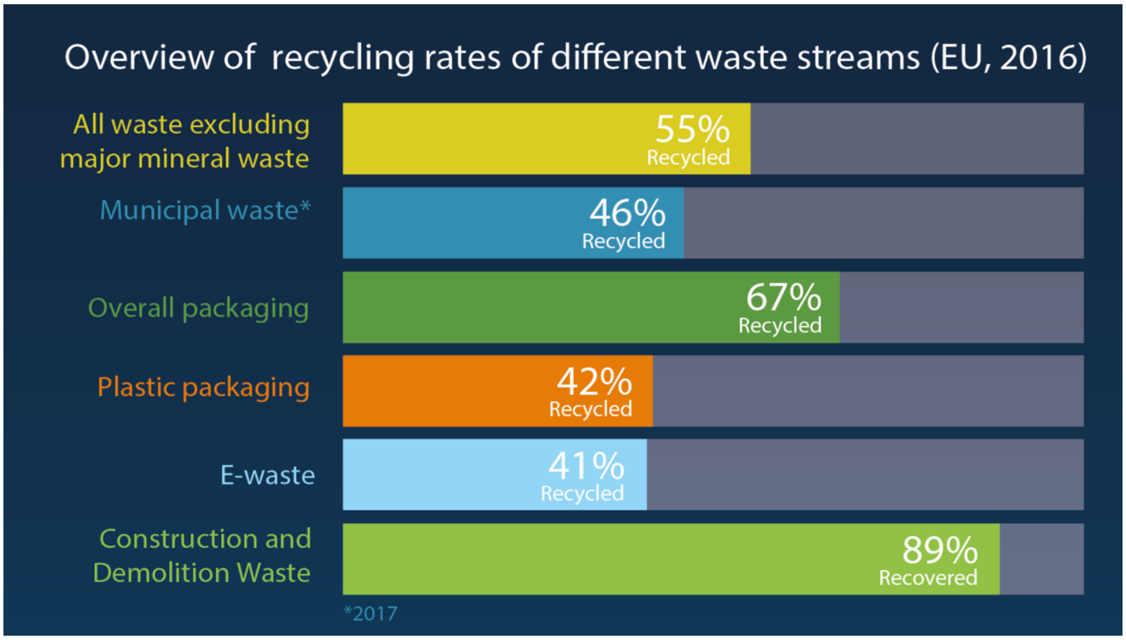


Figure 4.44: Overview of EU Recycling waste streams 2016 (Eurostat, 2016)

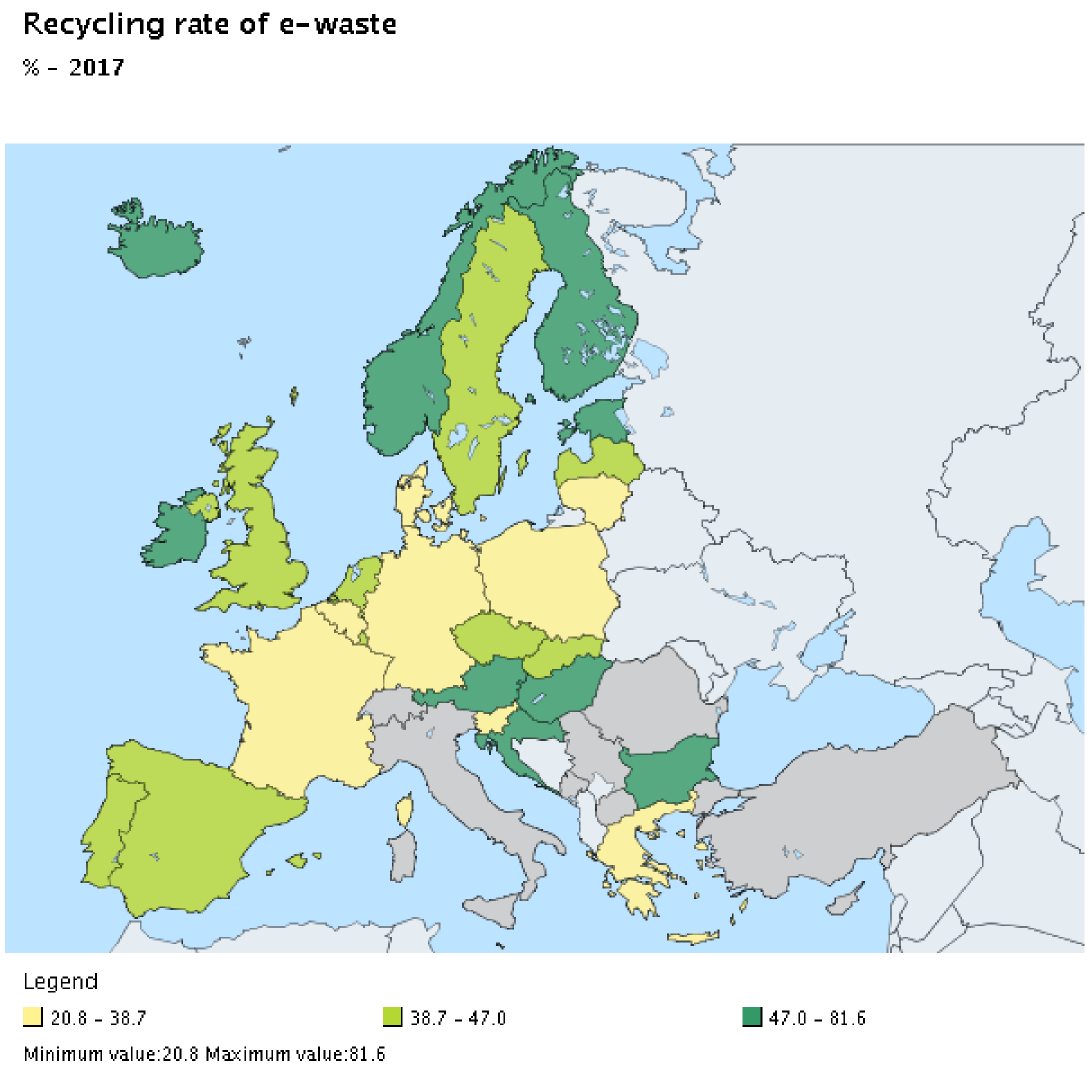


Figure 4.45: Recycling rates of e-waste (Eurostat, 2016)

Figure 4.45 was created/remodelled using Eurostat software from data collected for Eurostat but publicly available. The data table can be found in the Appendix. The indicator is calculated by multiplying the ‘collection rate’ as set out in the WEEE directive with the ‘reuse and recycling rate’ set out in the WEEE directive, where the ‘collection rate’ equals the volumes collected of WEEE in the reference year divided by the average quantity of electrical and electronic equipment (EEE) put on the market in the previous three years (both expressed in mass unit). The ‘reuse and recycling rate’ is calculated by dividing the weight of the WEEE that enters the recycling/preparing for re-use facility by the weight of all separately collected WEEE (both in mass unit) in accordance with Article 11(2) of the

WEEE Directive 2012/19/EU, considering that the total amount of collected WEEE is sent to treatment facilities (Eurostat, 2019).

The revised legislative framework on waste entered into force in July 2018**.** It sets clear targets for reduction of waste and establishes an ambitious and credible long-term path for waste management and recycling.

Key elements of the revised waste proposal include:

- A common EU target for recycling 65% of municipal waste by 2035;
- A common EU target for recycling 70% of packaging waste by 2030;
- There are also recycling targets for specific packaging materials:
    - Paper and cardboard: 85 %
    - Ferrous metals: 80 %
    - Aluminum: 60 %
    - Glass: 75 %
    - Plastic: 55 %
    - Wood: 30 %

- A binding landfill target to reduce landfill to maximum of 10% of municipal waste by 2035.
- Separate collection obligations are strengthened and extended to hazardous household waste (by end 2022), bio-waste (by end 2023), textiles (by end 2025).
- Minimum requirements are established for extended producer responsibility schemes to improve their governance and cost efficiency.

4.3.3.4 **The Positive Impacts of Recycling**

1. It reduces the amount of waste sent to landfill

2. It keeps valuable resources in the country

3. It creates employment at recycling centres, manufacturing new products)

4. It reduces litter and pollution

5. It reduces the requirement for extracting (mining, quarrying, and logging), refining and processing new raw materials

6. It turns waste into something useful or innovative

Example: Destaclean – Professional Waste Material Recycling Destaclean Oy is a material recycling company established in 1998. Its goal is to promote material recycling in accordance with Finnish waste legislation. The company's operations cover the entire construction waste recycling chain, from waste collection and processing to the recycling of materials (Destaclean, 2020).

The CE economics, like environmental economics is concerned with identifying and solving problems related to damage and pollution associated with the flow of residuals. In this context, the principles underlying the CE suggest that, by assuming the planet as a closed system, the number of resources depleted in a period is equal to the amount of waste generated in the same period. The principles of the CE thus reveal an idealistic ambition of pushing the boundaries of sustainable supply chain management practices. Such practices are ultimately concerned with the reduction or the delay of unintended negative impacts on the environment due to cradle to grave linear material flows (Genovese, 2015).

In Europe, socio-economic enterprises such as charities, voluntary organisations and not-for -profit companies are involved in the repair, refurbishment and reuse of various products. Ongondo's research characterises and analyses the operations of socio-economic enterprises that are involved in the reuse of information and communications technology.

Using the findings from a survey, this research specifically analyses the reuse activities of socio-economic enterprises in the UK from which Europe-wide conclusions are drawn (Ongondo, 2013). Demand for various scarce raw materials for the manufacture of electronic products has forced countries to rethink their strategies for managing WEEE. The findings of this report provide a detailed insight into the reuse operations of socio-economic enterprises and present and analyse previously unobtainable data. George presents a theoretical model incorporating the concept of circular economic activities, where constructing a CE model with two types of economic resources, namely a polluting input and a recyclable input. Overall, the results indicate that the factors affecting economic growth include the marginal product of the recyclable input, the recycling ratio, the cost of using the environmentally polluting input and the level of pollution arising from the employment of the polluting input (George, 2015).

4.3.3.5 **Four Essential Building Blocks of a Circular Economy**

1/ Circular Economy design:

- material choice optimised for circular setup
- design to last
- more modularisation/standardisation
- easier disassembly
- production process efficiency

2/ New Business Models:

- consumer as user
- performance contracts
- products become services

3/ Reverse Cycles:

- collection systems; user-friendly, cost-effective, quality preserving
- treatment/extraction technology: optimising volume and quality

4/ Enablers and favourable system conditions:

- cross-cycle and cross-sector collaboration facilitating factors
- favourable investment climate – availability of finance
- rules of the game are to quickly reach scale
- education of the public, university courses

(Based on EMF3, 2014)

Moving towards a more extensive CE could deliver many environmental and economic benefits including better security in the supply of raw materials, increased productivity, improved capacity to innovate, societal growth and employment.

Benefits of the Circular Economy include:

Less waste going to landfill sites

Less waste being generated, and the natural resources needed in manufacturing

Cost savings in manufacturing

Cost savings in raw materials

The creation of new business opportunities

The creation of new jobs

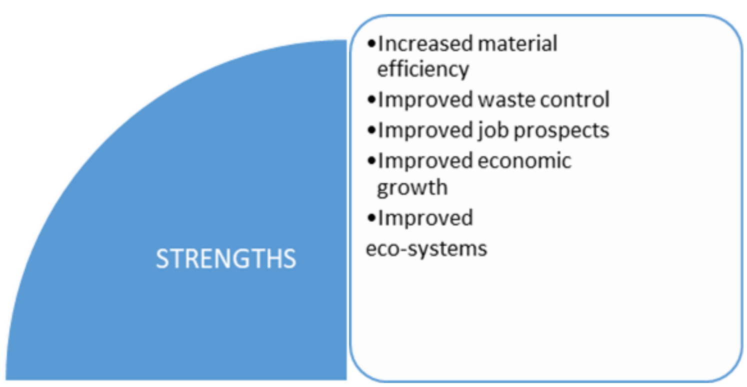
Improved conditions for funding/investment

The creation of new social norms around waste

What are the strengths, weaknesses, opportunities, and threats of the Circular Economy?

Figure 4.46: shows some of the key strengths and opportunities that are possible in a CE they far outweigh the weaknesses and threats.

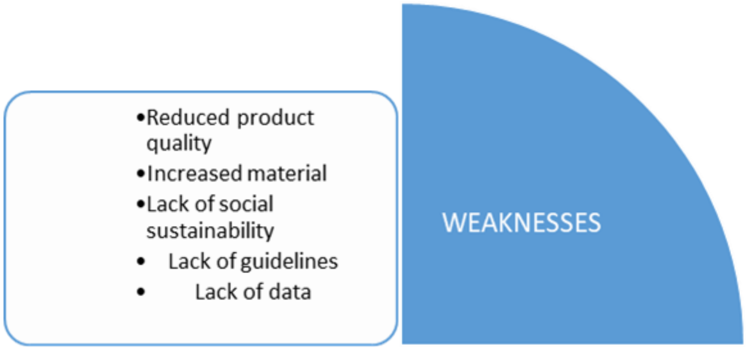
Figure 4.46: Circular Economy SWOT Analysis



With increased material efficiency, materials can be recycled, reused, and re-designed resulting in the reduced extraction of virgin raw materials. Delivering improved waste control is one of the top priorities for many cities especially the larger cities where it is easy for waste to go unnoticed and accumulate rapidly. Collecting waste, sorting it, treating it and recycling it is an expectation in the 21st century but it does come with its challenges. Having waste under control allows cities to be cleaner, greener with improved air quality. Improving waste control reduces our dependence on the extraction of virgin raw materials. Positive impacts from increased recycling rates are offset by reductions in landfill and waste management demand.

Improved CE eco-systems allows systems thinking to focus on non-linear systems where feedback loops play important roles. By creating closed loop systems that keep resources in use for longer, the CE increases the value of these resources to the organisation. The CE can be used to develop customer/consumer understanding of the benefits of the CE and promote a narrative that goes beyond waste management and recycling. Organisations can encourage consumers to purchase remanufactured products or showcase how they can reuse what they already have, this all helps to build confidence in such markets ultimately supporting the growth in the CE.

Improved economic growth – in the wake of businesses and governments, a growing number of financial institutions and investors have started to identify the circular economy as a positive framework to address current global environmental issues according to the Ellen Macarthur foundation. Improved economic growth normally results in an increased labour demand and in the circular economy this is marketed as being highly attractive to governments. The CE DG-Environment report stated that as the United Kingdom becomes more efficient at utilising resources and transitioning to a circular economy, employment is expected to grow more than the expected decline in extractive industries like oil and gas. Several explored scenarios for a transition to a circular economy found potential job increases of between 250,000 and 520,000 jobs and an overall decrease in the unemployment rate (Cambridge Econometrics, 2018). Although employment will decrease in some sectors, employment will generally increase overall. This trend can be mirrored throughout European cities. The waste sector, recycling services and repair services are the main sectors that will see big increases in employment.



In the circular economy products and materials are intended to remain in circulation for as long as possible, because of this many consumers believe that the quality of the products recycled will decrease in quality the more times they are recycled. This is a credible argument but there is no evidence to substantiate it. Quantifying the increases or decreases in material consumption will rely heavily on how well organisations collect data on these functions.

To add to the lack of guidelines there is a distinct lack of standards. Although in many circles they are discussing this issue, publishing actual standards are very premature or non-existent. The framework from this research will contribute to addressing this weakness.

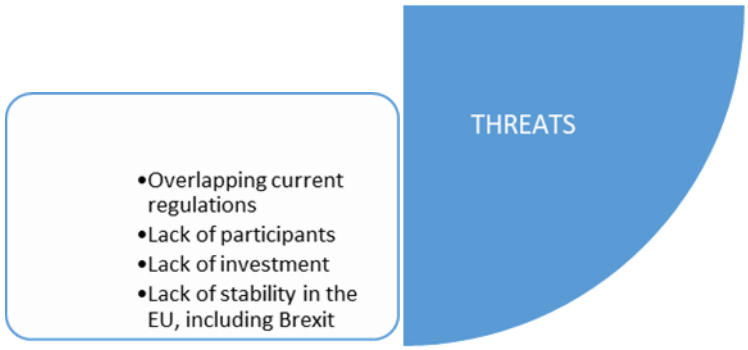
Lack of data may seem contradictory because of the vast amounts of data available but this lack of data refers to the lack of data collection and for specific areas like materials in components or waste generation important metrics for the CE these are either not collected or often not readily available when required. This weakness negatively impacts the ability of organisations, academics, governments and not for profit organisations to adopt, use report on and implement the circular solutions needed.

The transition to a circular economy requires more transparency to make a big leap forward. Currently, a particular challenge is data collection and access, as supply metrics such as material use and waste generation are either not collected at all or often not readily available when needed (Santschi, 2022).

The most important threat to successful transitioning to the circular economy is reducing waste. All sectors should be engaged in reducing the waste generated.

There is a growing need for organisations to contribute to the environment, including the circular economy. Most are claiming to do something, but this should be backed by the evidence. This can be done by implementing environmental management systems, hence the need for a management system standard on the circular economy. Being certified to a reputable CE management system is attractive to commercial leaders but also brings advantages to the organisation in just complying with the requirements of the standard. These advantages can include opportunities to minimise waste creation, creating new designs (circular design), innovative design for end of life, creating new jobs and reducing costs through resource efficiency. At a time when the jobs market is struggling to recruit and retain suitably experienced and skilled staff the circular economy is creating a whole new sector of jobs. Typical jobs in the CE are CE Consultant, Circular design engineer, CE researcher, CE university lecturer. There are also a lot of new businesses and start-ups based on circular economy business models that have opened. For example, a Zero waste shop that allows you to bring your own bags, bottles and containers, so you can buy products and collect the products in your own bags, bottles and containers eliminating the need for packaging and reducing the amount of packaging waste generated.

Increased innovation in the adoption of the CE, turns limited resources into unlimited recurring resources. This concept will correct to an extent the imbalances in natural resources supply and demand. Getting the message across to every person that there are strong positive links between, growth, jobs and resource efficiency in transitioning to a circular economy is a real opportunity.



Overlapping or even progressive regulations pose a threat to the CE. An example of this is the Regenerative Economy (RE). Definition: A regenerative economy is a circular economic system that benefits the environment and society.

While a CE aims to maximize the efficiency of resource use and design out waste, a RE aims to create systems that are regenerative by design. It focuses on replenishing resources and restoring ecosystems, aiming for long-term sustainability and resilience. This goes back to the regenerative design school of thought in section 4.2.2 and the EMF concept of being resilient and efficient, restorative and regenerative by design.

A lack of participants translates to a lack of resources both in expertise and financially. A growing number of policies and initiatives show confidence in the circular economy, but specific political, social, economic and technological barriers continue to exist. While policies are growing in some sectors other sectors are lagging or are not sufficiently strong and consistent. Organisations often lack the awareness, knowledge or capability to identify and pursue circular economy solutions. Technical skills and initial investment are required to identify, process and analyse datasets. Some organisations have assumptions that the CE is just another buzz word with no depth, and this prevents them from participating. In order for an international standard to be developed national standardisation bodies need to find experts and explain the concept and need for a CE standard to them, this takes time.

A lack of investment in measures to improve efficiency or innovative business models is inadequate because they are perceived as risky and complex.

4.3.3.6 **Circular Economy Business Models**

Circular Economy business models effectively keep products and materials circulating usefully for as long as possible. There are many ways of doing this depending on the business. In the introduction are the two conceptual models i.e., the linear model and the CE model (so no need for repetition here). If you base your circular business model on the CE and the principles of the CE, then your model should aim at:

Sourcing products and materials from the economy not from natural resources

Creating value for customers by adding value to existing products and materials

Maximising inputs for the business beyond the customers' requirements.

Figure 4.47 presents five business models of circularity that any business can adopt and apply to their own products.

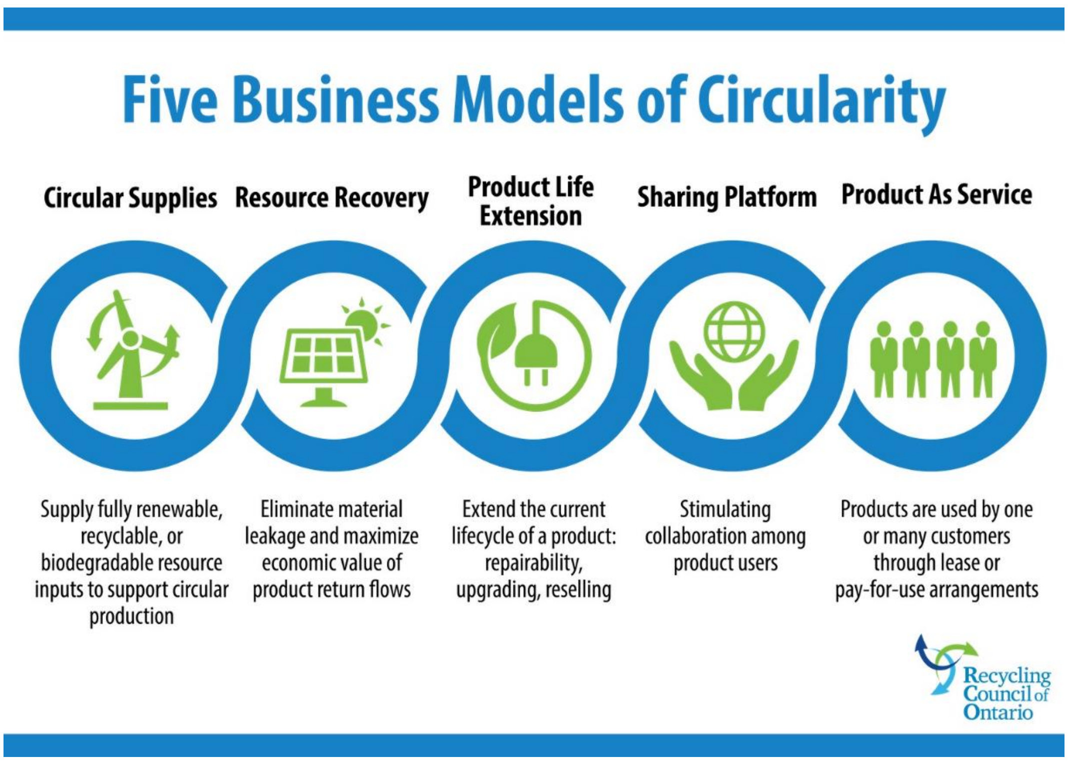


Figure 4.47: Five Business Models of Circularity (Source: Recycling Council of Ontario, 2020)

4.3.4 **Conflict?**

This section analyses and concludes the previous two sections on the Financial Economy and the Circular Economy.

Protection of the environment would become a reality only if it was perceived as economically viable and requiring no financial or behavioural sacrifices. Today, efficient solutions exist that can boost economic growth, while at the same time reducing our impact on the planet (Piccard, 2020).

It has been known or expected for a long time now that developed and developing countries around the world will not be able to sustain prosperity long term if the current economic model remains the same. The pressures on natural resources, including biodiversity, climate and air quality, is increasing. And, whilst everyone is coming up with innovative solutions to the replacement or extension of fossil fuels and the possibilities for increasing food production, it is very clear that the limitations of planet earth are being exceeded. We know that global warming is happening, and our greenhouse gas emissions are reducing far too slowly.

National governments often regulate organisations to minimise external costs to the public, such as regulating air pollution that results from the production of products and services. Complying with these regulations often incurs costs on organisations; however, it is in the organisations financial best interest to comply, as failure to meet these obligations under environmental regulations could result in even greater costs in penalties. Management system standards like ISO14001 Environmental Management can help organisations to introduce practices that let them meet their obligations, while also securing financial benefits for organisations, such as reducing energy costs, reducing greenhouse gasses, and minimizing waste.

Is there any conflict between the financial economy and the circular economy?

Description	**Financial Economy**	**Circular Economy**	**Conflict?**
The rising costs of raw materials	Yes – as materials become scarcer the costs increase	Yes – as costs increase more companies have to reduce the quantities, they can buy	An increase in cost for the financial economy, so there is less products in circulation and therefore less waste at end of life. This is a win for the CE.
The rising cost and amount of regulatory compliance	Yes – as regulation increases the costs of compliance also increases	Yes – as regulation increases less products get to market	No, regulation is absolutely necessary for the CE to happen
The increasing amount of waste being generated	Increasing waste means increasing costs to tackle it	Increasing waste highlights the need for the circular economy	Reducing waste by reusing materials to the maximum possible delivers production cost savings and less resource dependence.

This Table 10 in the Appendix shows that among the greater positive attribute of the Circular Economy there are barriers and challenges. Although these challenges were collated from research conducted by Ongondo, et al, the qualitative comments provide highlighted costs associated with the identified barriers to show that these are costs that need to be balanced against the good attributes of the Circular Economy. They present conflict if they are not offset with CE benefits.

4.4 What will be the Impact of a Circular Economy Standard to the Environmental Community?

4.4.1 Introduction

The Standards developing communities of ISO, IEC, CEN/CENELEC, National Committees and others are busy developing Standards for every conceivable technology or system and so, it is difficult to develop a new Standard that does not encroach on other Standards already being developed. The added value of this new Standard will be to develop a holistic and global approach for any Circular Economy project. The Circular Economy Standard will consider the key interactions taking place between the general issues and their contributions to Sustainable Development. These general issues will contribute to the implementation of the UN Sustainable Development Goals in a coherent and integrated way.

The general issues of The Circular Economy are:

- Sustainable procurement
- Sustainable consumption
- Effective management of materials
- Life cycle analysis
- Eco-design
- Industrial symbiosis/ecology
- Sustainable functionality

For this thesis submittal the above issues have been narrowed and condensed to concentrate research on four areas. These are:

- Resilience to Climate Change
- The importance of Eco-design

- Future thinking - Horizon 2020 – Research, Innovation
- Sustainable Development Goals

4.4.2 **Resilience to Climate Change**

Climate change refers to a broad range of global phenomena created predominantly by burning fossil fuels, which add heat-trapping gases to Earth's atmosphere. These phenomena include the increased temperature trends described by global warming, but also encompass changes such as sea level rise; ice mass loss in Greenland, Antarctica, the Arctic and mountain glaciers worldwide; shifts in flower/plant blooming; and extreme weather events (NASA, 2020).

Standards are fundamental to helping organisations advance climate change actions, whether they be management system Standards that shape organization culture and processes or new ISO technical Standards.

The Paris Agreement builds upon the Convention and brings all nations to a common cause to undertake ambitious efforts to combat climate change and adapt to its effects, with enhanced support to assist developing countries to do so too. The central aim of the Paris Agreement is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius. Additionally, the agreement aims to strengthen the ability of countries to deal with the impacts of climate change (United Nations Climate Change, 2020).

Global emissions are destroying our planet every day, the evidence for rapid Climate Change is compelling:

- Global temperature rise
- Warming oceans
- Shrinking ice sheets
- Glacial retreat
- Decreased snow cover
- Sea level rise
- Declining arctic sea ice
- Extreme weather events

- Ocean acidification

Most climate scientists agree the main cause of the current global warming trend is human expansion of the "greenhouse effect" — warming that results when the atmosphere traps heat radiating from earth toward space gases that contribute to the greenhouse effect, these are: water vapour (H20) methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2). (nasa.gov) The amount of greenhouse gasses in the atmosphere is higher than it would naturally be, resulting in changes to the world's climate. "The Greenhouse Effect means that in general the planet is getting hotter. But in some places the world is getting wetter, in other places it is getting drier and in other places it is getting windier. It all depends on where you live as to what effect climate change may have on you". Organisations with greenhouse gas (GHG) inventories are using the ISO Standard 14064-1 to guide their reporting of these greenhouse gas emissions. The working group (WG) that developed the standard anticipated the need to assess both direct and indirect emissions due to electrical consumptions of the gasses that cause climate change. ISO 14064-1 also allows extending the quantification of greenhouse gasses on voluntary and discretionary basis including other indirect emissions, for example employees delivering or collecting goods on behalf of the company, otherwise omitted from greenhouse gas reporting. A good contribution to resilience to climate change.

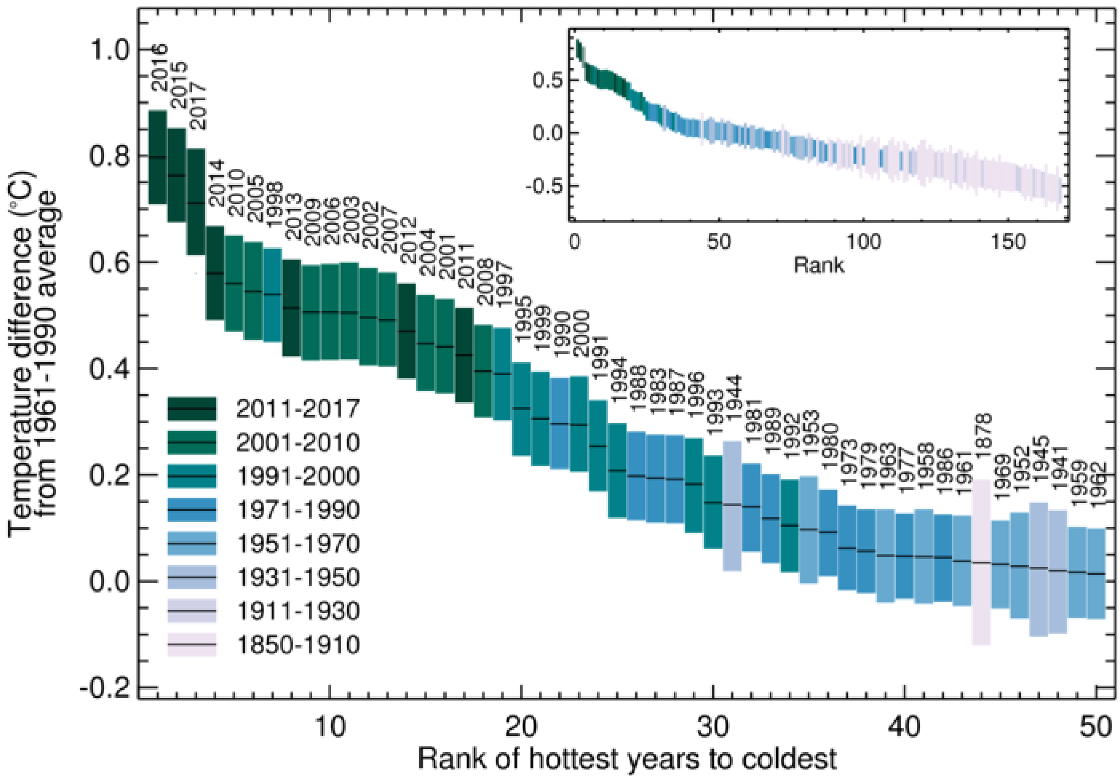


Figure 4.48: Atmosphere Measurements (Climate Research Unit, 2019)

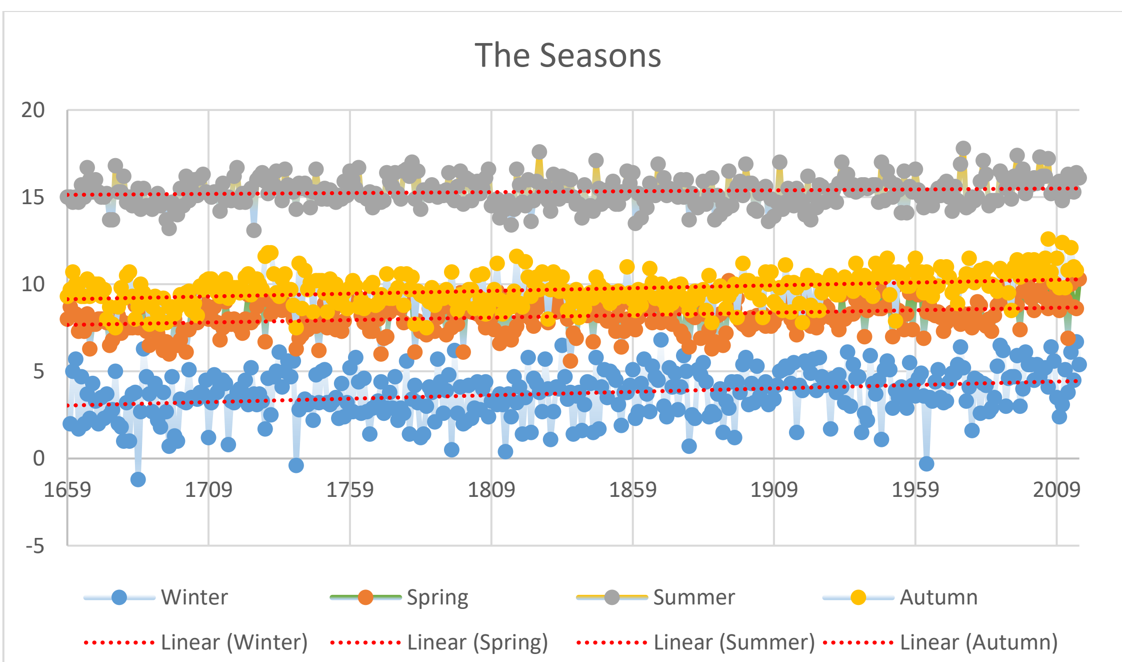


Figure 4.49: The Seasons

Source: (created from: Climate Research Unit, 2019) The datalink provided the dataset used to plot the seasonal variation. The dataset covered the seasonal mean temperatures annually from 1659 – 2017. The seasonal mean temperatures recorded ranged from:

- Winter: -1° to 6.8°
- Spring: 5.6° to 10.3°
- Summer: 13.1° to 17.8°
- Autumn: 7.5° to 12.6°

Microsoft excel was used to plot the seasonal data, plotted as a timeseries with nodes on the ends and nice colours to visualise the intensity. A trend line was added to the seasonal timeseries plots to show the gradients in the temperature, the temperatures are increasing.

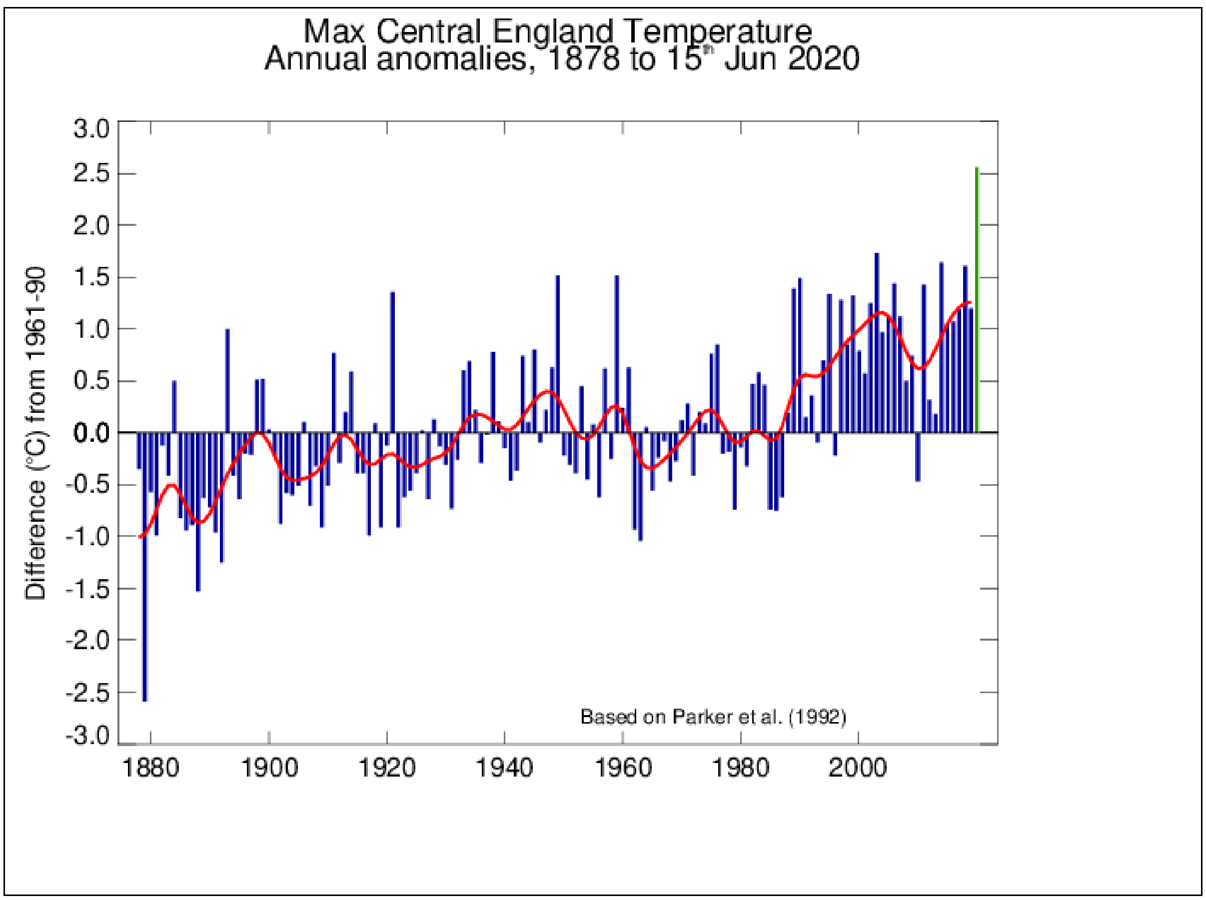


Figure 4.50: Max Central England Temperatures (Met Office Hadley Centre, 2020)

The two diagrams above Figure 4.50 visualising global temperature rises, clearly shows the highest temperatures have been in more recent years and Figure 4.50 visualising max central England temperature annual anomalies between 1878 and June 2020. Again, there is clear evidence of temperatures consistently increasing in recent years.

The United Kingdom is one of the leading nations developing standards on climate change and in particular "Adaptation to Climate Change" – ISO 14090 and "Adaptation to Climate Change" – Vulnerability, impacts and risk assessment – ISO 14091.

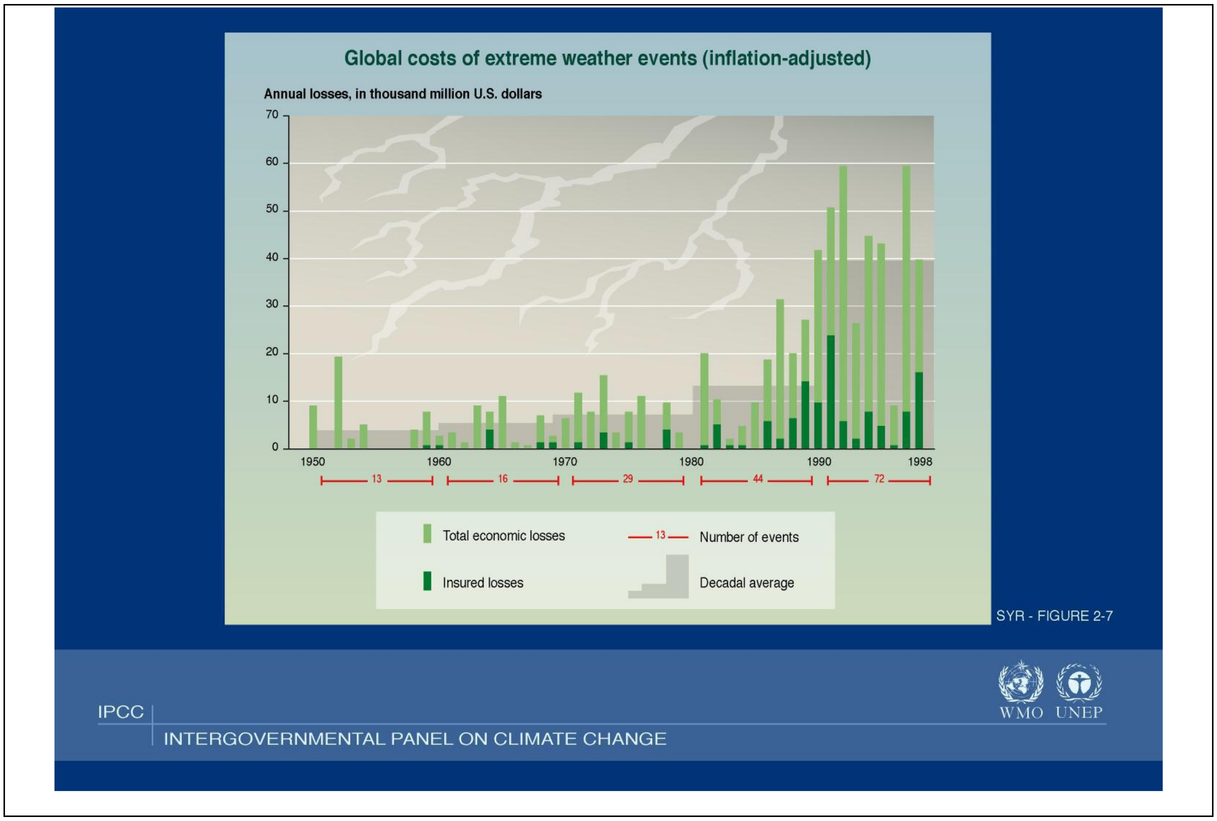


Figure 4.51: The Global Costs of Extreme Weather Events (John Dora Consulting Ltd, 2020)

It is difficult to make judgements or comment on the figures in Table 11 below, because how much is attributed to the powers that be and how much is attributed to human behaviour is hard to tell, but we know we are contributing to the increase and severity of these events. Available studies for economic losses from river floods and storms in Europe suggest that the observed increases in losses are primarily because of population increases, economic wealth and developments in hazard prone areas (EEA, 2017).

What is the trend in Economic losses from Climate-related extremes in Europe?				
Country	**Losses (million Euro)**	**Insured losses (million Euro)**	**Insured losses (%)**	**Fatalities**
Austria	13,489	4,156	31	595
Belgium	4308	2531	59	2168
Bulgaria	2452	129	5	205
Croatia	3014	74	2	722
Cyprus	386	8	2	77
Czechia	10533	3554	34	220
Denmark	10336	6307	61	42
Estonia	108	33	31	9
Finland	1959	397	20	4
France	62059	30961	50	23415
Germany	96494	45188	47	9856
Greece	7319	113	2	2431
Hungary	6035	137	2	703
Iceland	88	43	50	52
Ireland	4014	2059	51	69
Italy	64673	2918	5	20657
Latvia	412	49	12	103
Liechtenstein	6	3	58	0
Lithuania	976	7	1	69
Luxembourg	718	424	59	130
Malta	63	26	41	7
Netherlands	8111	3771	46	1729
Norway	3597	1977	55	40
Poland	15057	1027	7	1217
Portugal	6869	584	9	3108
Romania	11065	60	1	1310
Slovakia	1669	106	6	112
Slovenia	1690	203	12	241

Spain	37106	4508	12	14611
Sweden	4272	1165	27	46
Switzerland	18805	9621	51	1160
Turkey	4405	635	14	1682
United Kingdom	50504	35106	70	3535

Table 11: Impacts of extreme weather and climate related events in the EEA Member countries (1980-2017) (source EEA, 2017)

4.4.3 The Importance of Eco-design

"Eco-design" is the integration of environmental aspects into product design with the aim of improving the environmental performance of the product throughout its whole life cycle and is regulated by the Directive 2009/125/EC of the European Parliament.

The Directive seeks to achieve a high level of protection for the environment by reducing the potential environmental impact of energy-related products, which will ultimately be beneficial to consumers and other end users. Sustainable development also requires proper consideration of the health, social and economic impact of the measures envisaged. Improving the energy and resource efficiency of products contributes to the security of the energy supply and to the reduction of the demand on natural resources, which are preconditions of sound economic activity and therefore of Sustainable Development. (Online - Directive 2009/125/EC) The concept of the Circular Economy relies on the idea of using resources for as long as possible then re-use, repair, recycle and put back into use. Within this concept engineers have a vital role to play in the material selection for new products, standardisation of components, design-to-last products, design for easy end of life sorting, separation or reuse of products and materials.

Since 80% of all environmental impacts of a product during its lifecycle originate in its design phase, the Union policy framework should ensure that priority products placed on the Union market are 'eco-designed' with a view to optimising resource and material efficiency. This should include addressing, inter alia, product durability, repairability, reusability, recyclability, recycled content and product lifespan. Products should be sustainably sourced and designed for re-use and recycling. These requirements will have to be implementable and enforceable. Efforts will be stepped up at union and National level to remove barriers to eco-innovation (EC, 2018).

Electrical and electronic products are particularly significant in designing for the Circular Economy. Their repairability is important to consumers, and they contain valuable materials that should be made more recyclable (e.g., rare earth elements in electronic devices).

In order to promote a better design of electrical and electronic products, the European Commission will emphasize Circular Economy aspects in future product design requirements under the Eco-design Directive, the objective of which is to improve the efficiency and environmental performance of energy related products. In the future, issues such as repairability, durability, upgradability, recyclability, or the identification of certain materials or substances will be systematically examined. The Commission will analyse these issues on a product-by-product basis in new working plans and reviews, taking into account the specificities and challenges of different products such as innovation cycles and in close cooperation with relevant stakeholders (EC, 2015).

In order to make products fit for a climate neutral, resource-efficient and Circular Economy, reduce waste and ensure that the performance of front runners in sustainability progressively becomes the norm, the Commission is proposing a sustainable product policy legislative initiative. The core of this initiative will be to widen the Eco-design Directive beyond energy-related products to make the Eco-design framework applicable to the broadest possible range of products and make it deliver on circularity.

This paragraph above shows the commitment of the Commission in the drive towards its goals for the European environment.

For companies manufacturing products, whether mechanical, electrical, or electronic, or any combination of the three these products can be designed specifically to make them easier to repair or refurbish during its product life cycle. This also allows design engineers to design their products for reusability and the recycling of the materials used once the products have reached their end of life and become waste. An increase in environmental awareness and the introduction of challenging environmental regulations already highlighted in this document and seen in demonstrations around the world have put pressure on designers to include the environmental performance of products together with traditional and sometimes regional or local design objectives throughout the design process. This is a feature of product life extension – design products that last. Extending the life of a product allows it to remain in use for as long as possible, one of the three core principles of the CE. This may involve designing products to be both physically and emotionally durable or it may require innovative approaches that allow the product to adapt to a user's changing needs as time passes. Products that resist damage and retain their emotional appeal can be used and reused multiple times, potentially by many different users (EMF4, 2012). Smart systems will boost circularity by utilizing the finite design related resources better, with processes such as rapid prototyping and enhanced testing (Ghoreishi and Happonen, 2020).

Life cycle assessment (LCA) is perhaps the most sophisticated and commonly used tool for analysing and quantifying the consumption of resources and their environmental effect throughout the entire life cycle of a product. The results from LCA can be used for eco-design, ecologically related label acquisition and environmental regulation certifications (Jeong, 2015).

The Eco-design process addresses ways to improve the environmental performance of many consumer goods, such as washing machines, vacuum cleaners, televisions, refrigerators etc by assessing environmental aspects over the entire lifecycle, taking into consideration which improvements are most feasible.

4.4.3.1 **Implementing Principles for Eco-design**

Eco-design encourages organisations to generate more integrated, efficient, and sustainable pathways for manufacturing through innovative design. To implement Eco-design principles into a manufacturing facility, the designers should be designing products that are:

- Easily assembled and disassembled including batteries and parts that are susceptible to breaking.
- Easily accessible and identifiable.
- Using the minimal number of components and materials.
- Using the minimal number of joints for assembly.
- Preferably using standard parts especially joining products like nuts and bolts.
- Using common parts across different products like power supplies.

- Using modular parts.
- Using materials and components suitable for reuse and recycling.
- Capable of developing a market for spare parts.
- Shaped to accommodate the recycling of the packaging.

Eco-design requirements allow industries to distinguish themselves from low cost, low performance imports. As Industry drives towards eco-design the bottom feeders will drop out of the marketplace.

LCA is a fundamental tool used in Eco-design. However, it can be costly and resource intensive. We take steps towards the automation of the inventory and impact analysis stages of LCA via the proposal and development of Case-Based Reasoning (CBR) procedure to estimate the ecological effects of a product (Jeong, et al, 2015) LCA requires life cycle thinking that examines all the stages of the life cycle in a certain activity or product to identify the widest range of relevant sustainability issues. ISO already has a technical committee ISO TC 207/SC5, that is developing standards on LCA, the current standard is ISO 14040:2006 – Environmental Management – Lifecycle Assessment – Principles and Framework. LCA described in the ISO Standard series ISO 14040-44, accounts for the impacts from all the stages implied in the wind farm cycle. The analysis of the environmental impacts along the entire chain, from raw materials acquisition through production, use and disposal, provides a global picture determining where the most polluting stages of the cycle can be detected. The general categories of environmental impacts considered in LCA are resource use, human health, and ecological consequences. The diagram below Figure 4.52 is from this Standard.

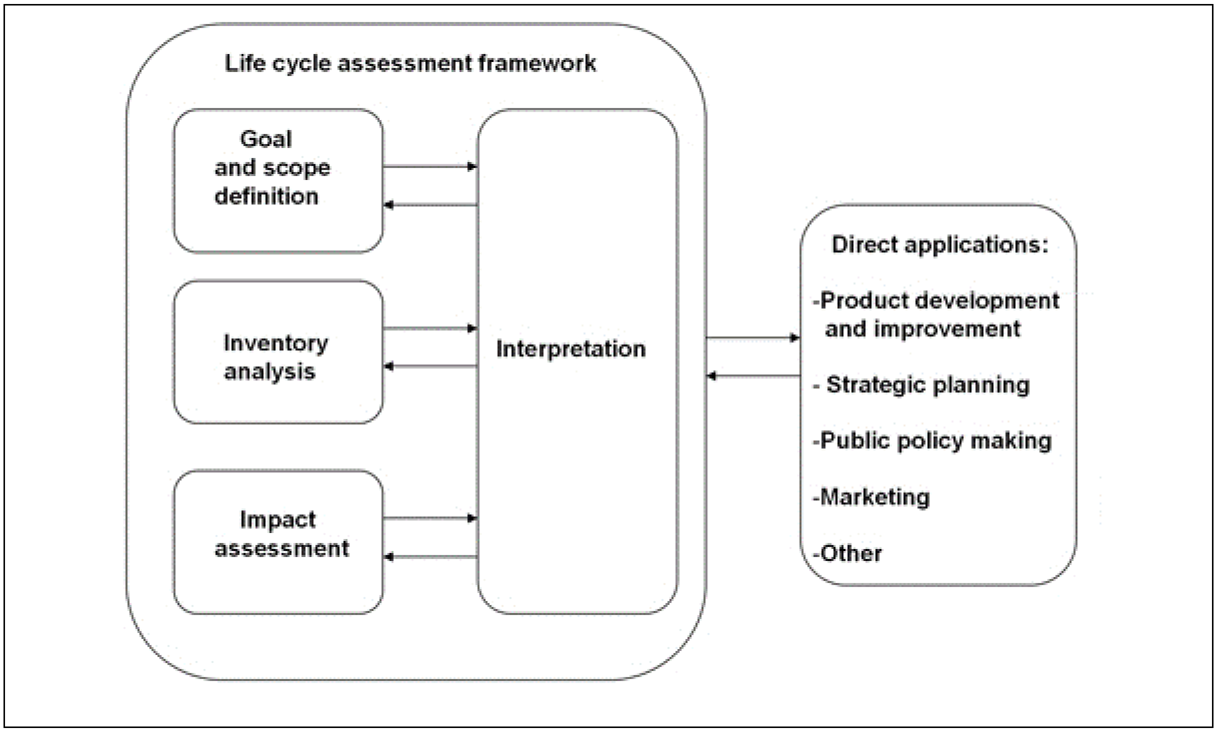


Figure 4.52: Life Cycle Assessment Framework (Source: Wind Energy the facts)

Design has a great role to play in sustainability. Some issues of sustainability and their impact on design remains poorly studied. Specifically, when it comes to the issue of local value creation, the literature in design is still limited. However, the Local Value Creation (LVC) thinking can be a great insight for designers to develop more eco-innovative concepts, through new product design, new services, and new business models (Tyl, et al, 2015). The concept of LVC can be defined as "economic activities using locally available input flows and generating output flows for the local community". As a result, the definition of LVC shall include both the territorial and lifestyle perspectives. Designing a local product therefore consists of setting constraints (raw materials, needs, economics, human skills, etc) in each physical area all along the lifecycle, from raw material extraction to end of life (Tyl, et al, 2015). A key aim of LVC is to minimise distances between value creation points. Secondly it is essential to enable local value creation all along the product life cycle with minimal environmental impacts and aligned with a sustainable eco-design method. Environmental concerns will cause consideration of durability in local production so that constraints to input and output materials can be maintained. Creating local value in this context means creating value with short loops, quite like those referred to previously in

Figure 4.29. LVC in eco-design will expand the current thinking of the CE. This area will require a lot of thought, but I believe it is conducive to the sustainability concepts of the CE. This approach can be used in this research to expand the current model of the CE.

4.4.4 **Future thinking - Horizon 2020 – Research, Innovation**

The Horizon 2020 Work Programme 2016-2017 proposed to invest 650 million Euros in focussing on "Industry 2020 in the Circular Economy", which grants funds to demonstrate the economic and environmental feasibility of the Circular Economy approach. While at the same time giving a strong impetus to the re-industrialisation of the European Union. Three years on since its inception Horizon 2020 has become a very popular and successful beacon for excellent research and innovation. It empowers researchers, innovators, and organisations to seek answers to big common challenges, to achieve European consensus.

There are plenty of research projects focussing on the Circular Economy within this combined sustainability and climate change area. With Horizon 2020 in gathering pace, a graphical representation of the success rate of Horizon 2020 applications per Member State 2014 to 2016 is captured below. The raw spreadsheet data is in the Appendix, (ECHA, 2020). The success rate of applications is calculated according to the following formula:

(No of applications in retained proposals) / (No of applications in eligible proposals) *100

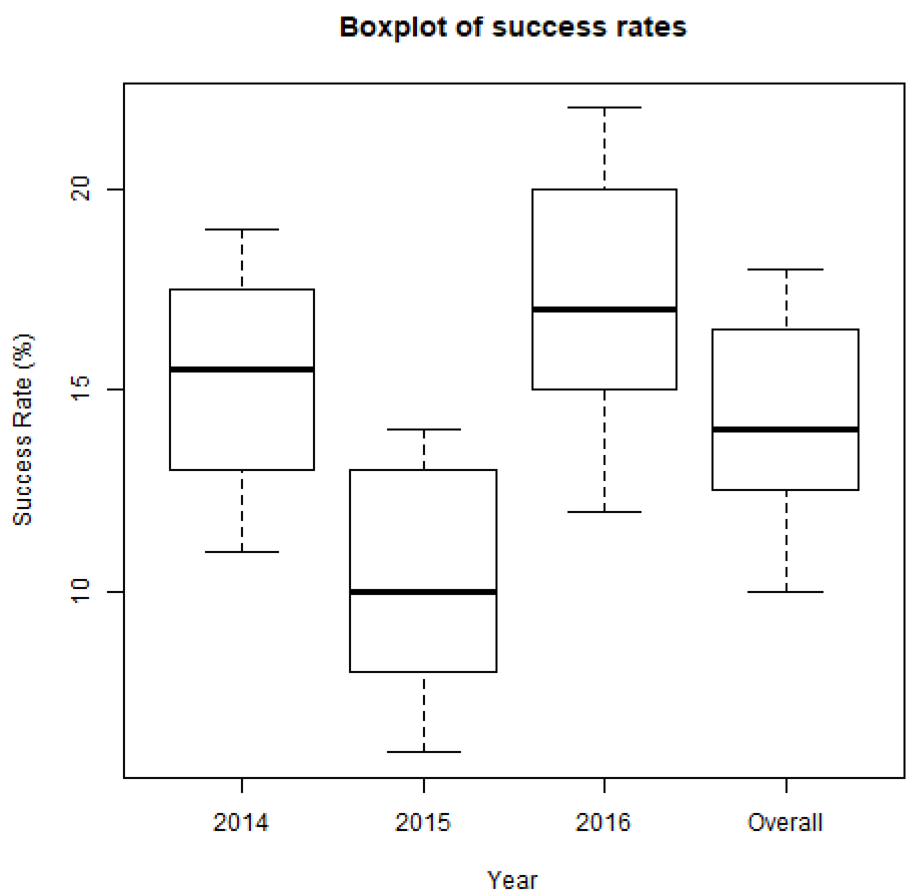


Figure 4.53: Horizon 2020 applications – “Boxplot”

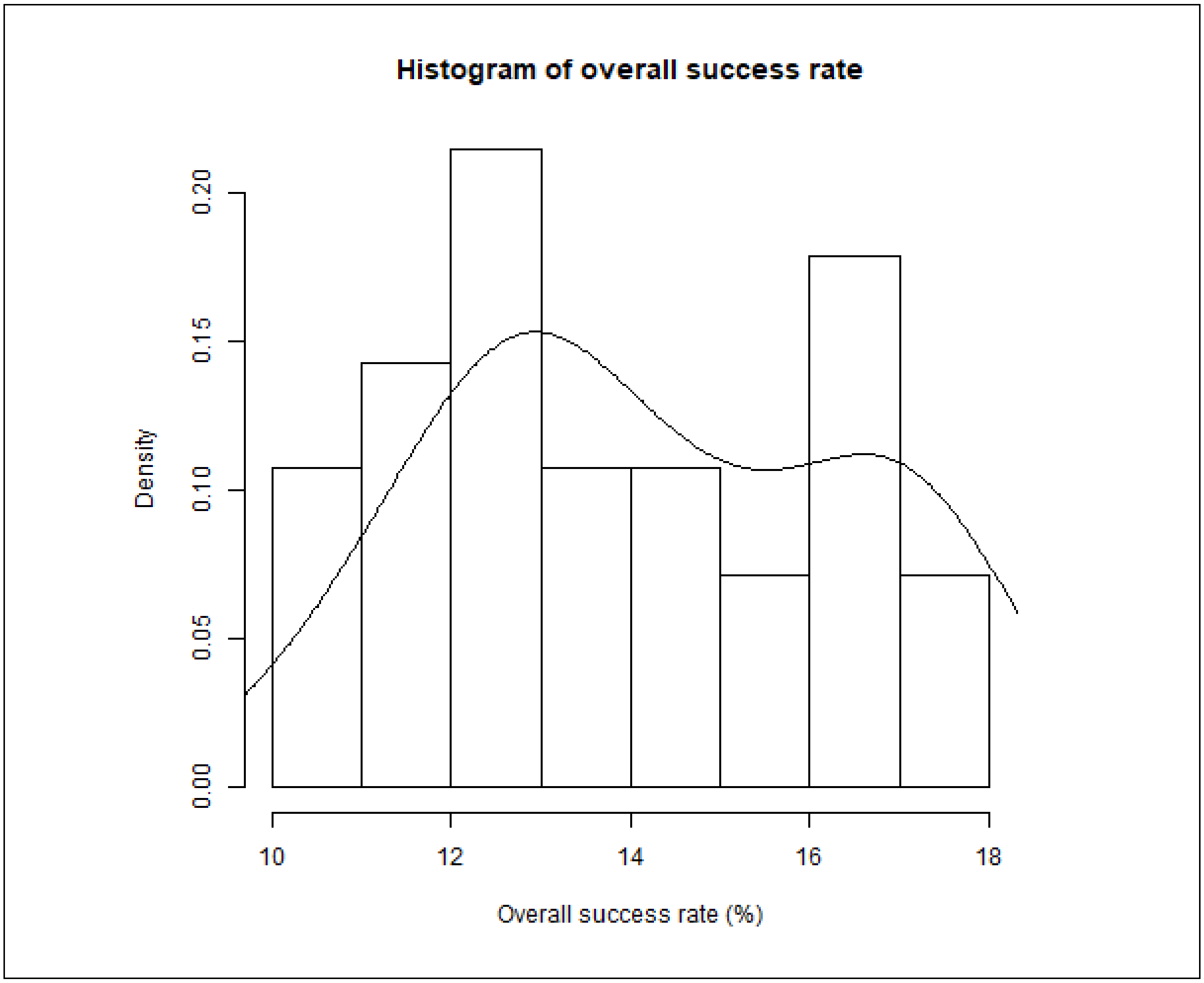


Figure 4.54: Horizon 2020 applications – "Histogram"

4.4.4.1 **Industry 4.0**

Industry 4.0, otherwise referred to as the Fourth Industrial Revolution, is a phenomenon driven by both an application pull and a technology push. It is the latest industrial system which functions an integration of manufacturing operation systems and information and communication technologies (ICT). Industry 4.0 organises the deployment of distributed automation and data exchange in manufacturing technologies, it is based around the Internet of Things (IoT), cyber-physical systems, big data, AI and cloud computing to create the "smart factory", where physical machines are monitored and controlled in pseudo real-time and autonomous decentralised decision-making manages the process. Industry 4.0 technologies have the potential to unlock a circular economy through the tracking of in-use products by embedded sensors in order to monitor maintenance requirements (Charnley, et al, 2019).

Recent approaches at EU level, advanced within the EU Research and Innovation Programme are related to 'Industry 4.0' – a new production paradigm aimed at developing a more sustainable and Circular Economy that requires appropriate policies, such that" production systems and value chains offer the opportunity to produce products more resource-efficiently and in a more sustainable fashion (Botezat, et al, 2018).

Industry 4.0 aims to achieve a higher level of operational efficiency and productivity, as well as a higher level of automation. Industry 4.0 based technologies are enablers that will pave the way in integrating CE principles through tracking products post -consumption and recovering components, Figure 4.55 incorporates several data centric solutions for circularity. With the ability to collect data from operations, processes and objects, digital technologies can help identify possible failures that create waste and to prevent further failures (Ghoreishi and Happonen, 2020).

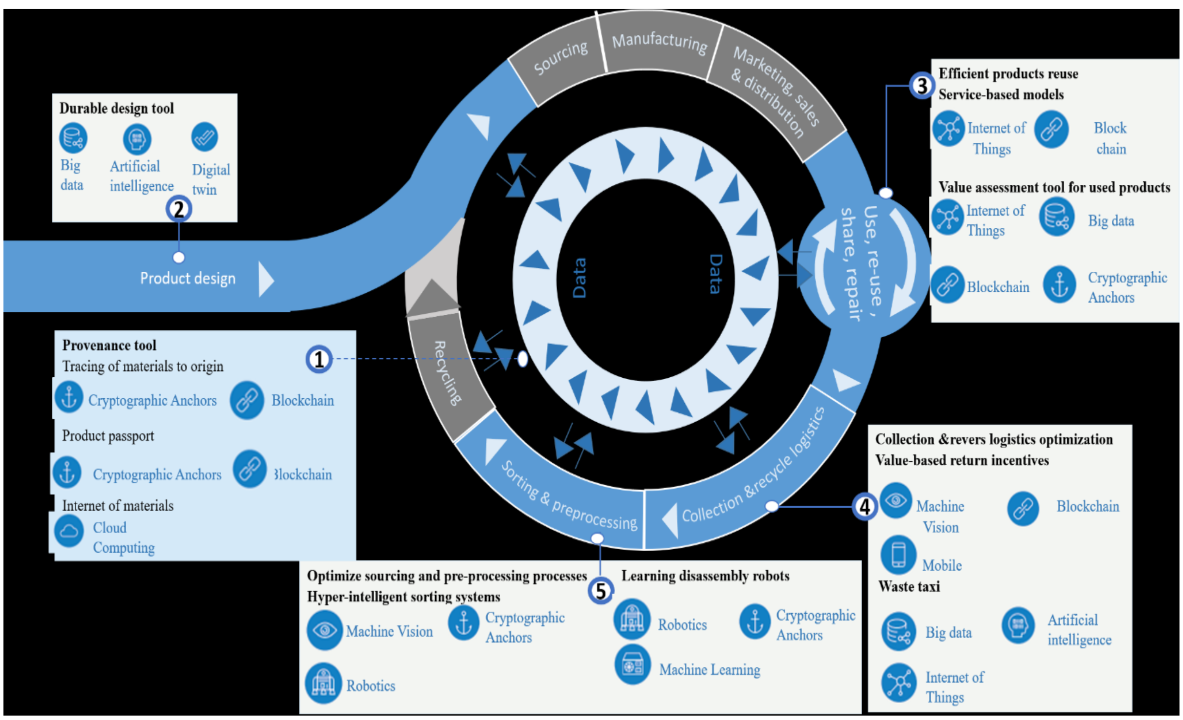


Figure 4.55: Industry 4.0 solutions for circularity (Ghoreishi and Happonen, 2020)

Innovative digital technologies have enabled the formation of multiple Product Service-Systems (PSS) with considerable economic, environmental and societal benefits. One of the most promising paradigms, which is inspired by business models and value propositions is the concept of the CE (Pagoropoulos, et.al, 2017).

4.4.4.2 **University Courses**

For the Circular Economy to be sustainable, it is essential that current and future academics, designers, engineers, strategists and marketers etc, are well equipped with the resources and skills needed to tackle circular economy advances and solutions. They need to think with a systems mindset to understand the CE concept. Although this section is titled university courses it includes pre-university, technical colleges and even "A" Level studies where applicable. It all plays a vital role in inspiring the next generation of Circular Economy practitioners.

Cranfield University - Cranfield University launches "World First" Circular Economy MSc the part-time postgraduate course - Technology, Innovation and Management for a Circular Economy will fuse expertise in engineering, logistics and environmental sciences with programs in business and finance. The course will focus on how business can be restorative and regenerative rather than the "take, make dispose" model traditionally followed.

University of Bradford – We offer the world's first and only MBA focussed on the Circular Economy. This new economic model aims to:

- ❖ Use resources and energy more effectively
- ❖ Reuse products and materials
- ❖ Deliver increased profit for organisations

The curriculum has been developed in partnership with the Ellen MacArthur Foundation and you will study topics including – regenerative product design, new business models, reverse logistics, materials, resources, energy and competitiveness and operations, marketing and strategic management.

Lund University, Sweden – Circular Economy – Sustainable Materials Management. This course looks at where important materials in products we use every day come from and how these materials can be used more efficiently, longer and in closed loops. This is the aim of the Circular Economy, but it does not happen on its own. It is the result of choices and strategies by suppliers, designers, businesses policymakers and all of us as consumers (Lund University, 2020).

Cambridge University – The Cambridge Circular Economy Programme – This is an intensive 2-day programme to provide business leaders with the grounding required to understand these principles, consider their application, and explore opportunities from this approach.

The Exeter Centre for Circular Economy (ECCE) – is a new research centre comprising staff based in three locations. They are a multi-disciplinary team composed of economists, engineers, designers, sociologists, management academics and practitioners. The ECCE has developed a new part-time, flexible online MSc level programme available from 2021, designed to support current and potential decision makers and leaders within organisations to develop the opportunities from CE offers and how to translate the theory into practice (Exeter University, 2020).

4.4.5 **Sustainable Development Goals**

Figure 4.56. Sustainable Development Goals (UNESCO, 2020)

The United Nations (UN) Sustainable Development Goals (SDG's) in Figure 4.56 are the blueprint to achieve a better and more sustainable future for all. They address the global challenges we face, including those related to poverty, inequality, climate change, environmental degradation, peace and justice (un.org). Although there are seventeen Sustainable Development Goals (was fifteen) as illustrated in Figure 4.56 of this thesis. The focus for the Circular Economy is Goal number twelve Responsible Consumption and Production. But the Circular Economy will contribute to SDG3 – Good Health and Well-Being through environmental legislation (RoHS and REACH), SDG6 – Clean Water and Sanitation through CE waste management programs, SDG11 – Sustainable Cities and Communities through consideration of the CE at different levels and SDG13 – Climate Action through resilience to climate change. Other SDGs could also be included as CE practices and related business models can help to achieve several of the sustainable development goal targets. The strongest relationships exist between CE practices and targets of SDG 6 (Clean Water and Sanitation), SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Work and Economic Growth), SDG 12 (Responsible Consumption and Production) and SDG 15 (Life on Land).

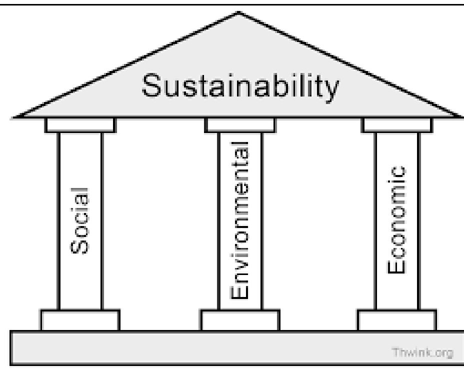


Figure 4.57: The 3 Pillars of Sustainability (Chokshi, 2017)

The SDGs are based on the foundation of sustainability, this foundation encompasses social, environmental and economic interests as shown in Figure 4.57. All three are required to be in equilibrium to level and stabilise the roof of sustainability. If any one of the pillars become unstable then the whole system is in danger of being unsustainable. The CE also has foundational roots in sustainability; **Social** – the CE aims to reduce the negative impact on human health by removing harmful chemicals from products, reducing pollution and climate change but also creating more employment and saving money through innovative eco-design; **Environmental** – the CE aims to reduce the dependency on new raw materials by increasing recycling of products, protect the environment by better waste management and resilience to climate change and Economic – the CE aims to rejuvenate innovation in recycled/reuse of products and boost economic growth.

Reducing our environmental impact, promoting the use of renewable sources of energy and encouraging responsible purchasing decisions are just some of the ways that ISO Standards contribute to Sustainable Consumption and Production (ISO, 2020). The concept of the CE and its implementation is gathering pace, but it is not the only sustainability concept being developed. See Figure 4.58 below.

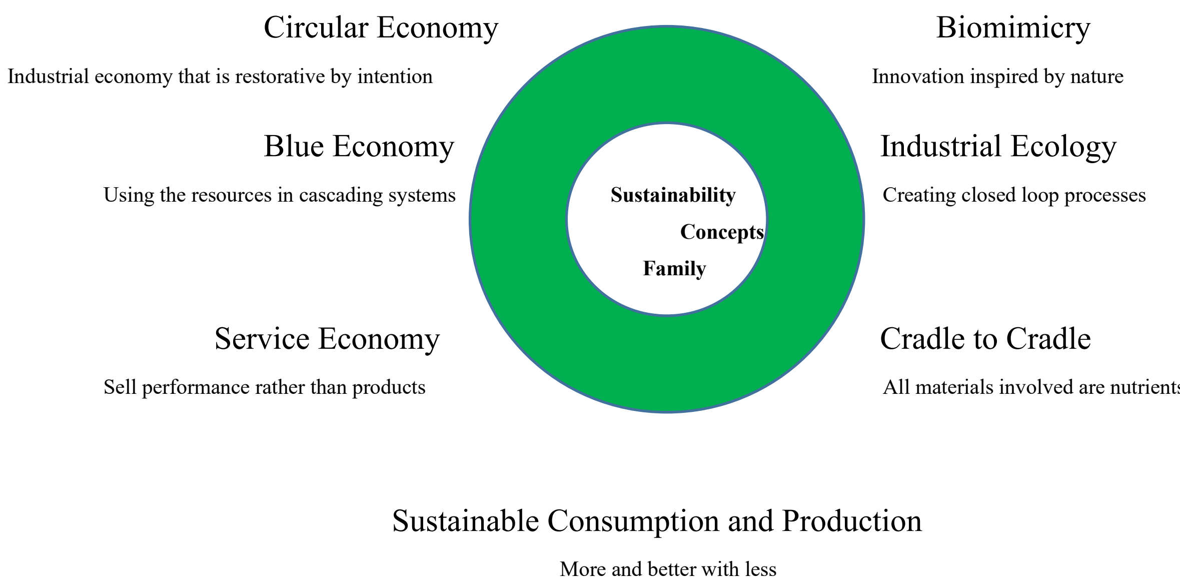


Figure 4.58: Circular Economy within the framework of other sustainability concepts (redrawn based on Swiss Academy, 2014)

Since the real target of sustainability is to ensure that raw materials are not wasted and that renewable resources are regenerated and continue to fulfil the needs of future generations, then actual focus must be on the actual quantities of resources that enter and exit the economy. For circularity to thrive, clarity is needed to ensure that the resource use considers the sector where the resource is being used. Each of the different sectors of the economy have different patterns of material flow, some, such as food, do not add much to societal stocks, whilst others, such as construction, contribute intensively to what is added to the national stocks (Biois, 2011).

The intermeshing of disciplines from the natural sciences, social sciences, engineering and management has become essential to addressing today's environmental challenges. Sauve, (2015) explores three alternative environmental concepts used in transdisciplinary research, and outlines some of the epistemological and practical problems that each one poses. It pays particular attention to the increasingly popular concept of the circular economy and contrasts it with the more commonly used concepts of environmental sciences and sustainable development (Sauve, et al, 2015).

Ghilsellini's research introduces the alternative concepts of trans-disciplinary research that impact or influence the circular economy. This is massively important in getting the broad picture on the CE. Sustainable development requires balanced and simultaneous consideration of the economic, environmental, technological and social aspects of an investigated economy, sector or individual industrial process as well as of the interaction among all these aspects. The CE has the potential to understand and implement radically new patterns and help society reach increased sustainability and wellbeing at low or no material, energy and environmental costs (Ghilsellini, et.al, 2015).

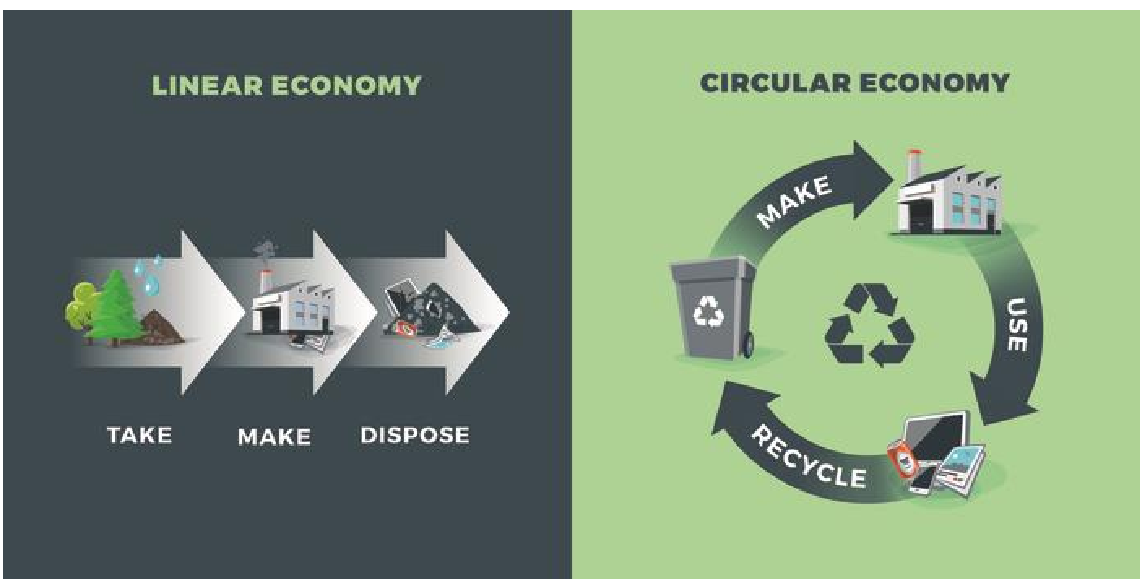


Figure 4.59: Fostering Sustainable Consumption and Production (Marchand, 2019)

One of the targets of SDG is to substantially reduce waste generation through prevention, reduction, recycling and reuse – SDG 12 Responsible consumption and production. IEC have developed a key publication (IEC 62474) which establishes the requirements for reporting the substances and materials included in electronic and electrical products (Marchand, 2019). Figure 4.59 returns to the linear and circular economy models to affirm that standards are needed like IEC 62474 that also facilitates the processing of data by defining a common data format, validating an open database and listing substances, substance groups and common material classes. Figure 4.60 links the relevant SDGs to the context of CE practices.

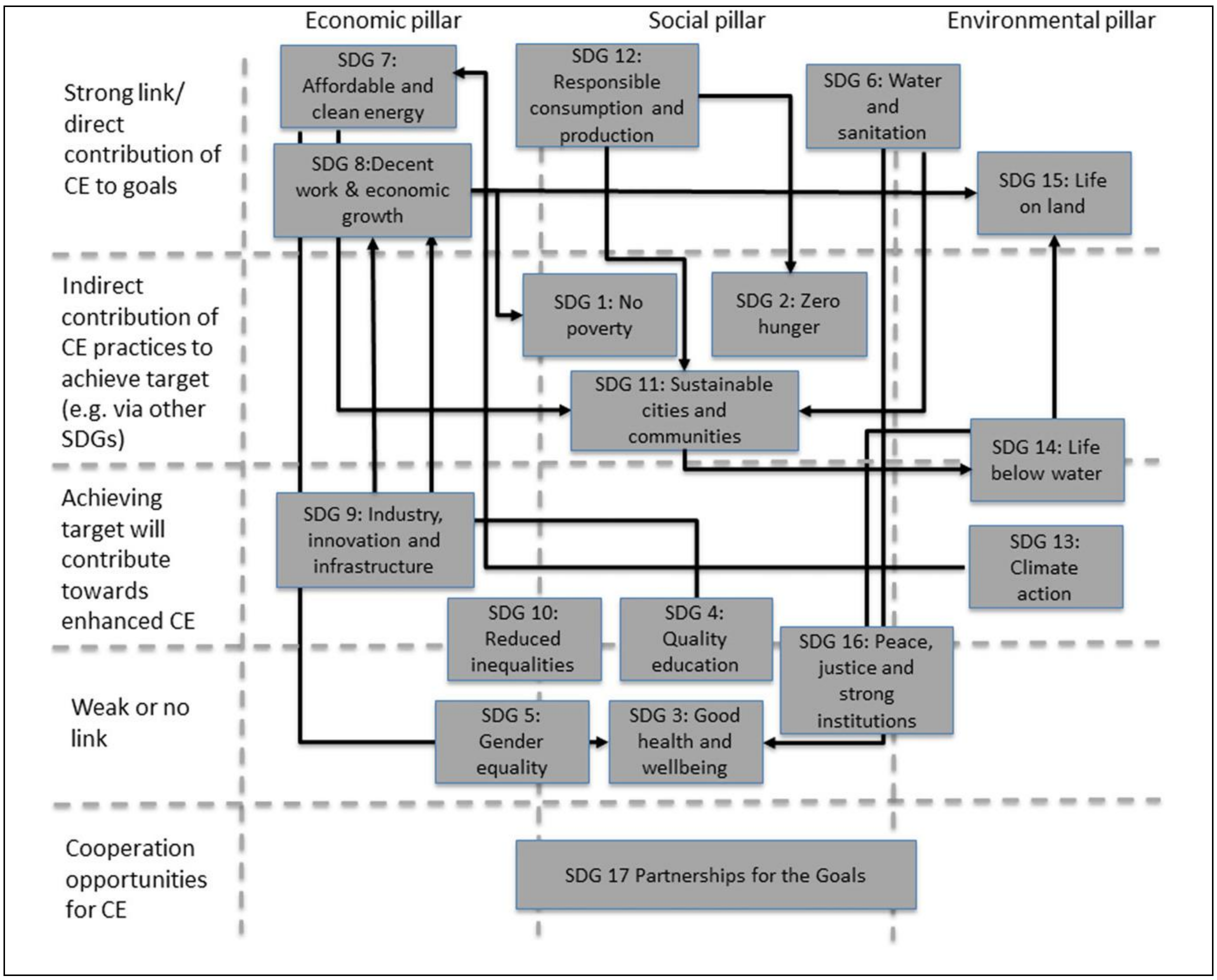


Figure 4.60: Relationships between Sustainable Development Goals in the context of CE practices (Schroeder et al, 2018).

Of the fifty-four materials that are critical for Europe, 90% must be imported, primarily from China. The relatively limited availability of these raw materials will lead to (more) geopolitical tensions. That, in turn, will impact on the price of raw materials and the security of supplies, and thus on the stability of the Dutch and European economies. This development can also lead to an increasing disparity in access to raw materials, whereby the poorest population groups will have the greatest disadvantages. This will affect the non-achievement of the SDGs (Ministry of Infrastructure and the Environment, 2016).

Sustainable Standards are standards and regulations that underpin environmental claims and the sustainable development goals. Sustainable standards are driving the push for organisations to deliver on their environmental responsibilities. Requirements for achieving net zero, pollution reduction, climate change and environmental regeneration like reversing bio-diversity loss are high on the agendas of most organisations. Sustainable standards rely on data analysis to inform the standards users of requirements to achieve the intended goals. For example, in ISO 14064-1, there is a requirement for the organisation using the standard to identify and document its data for each source or sink classified as direct or indirect emissions and removals. This will include both primary and secondary data. It continues with a requirement for the organisation to select or develop data models for the quantification approach. This research takes primary data and secondary data to programme a RFID chip implanted in the product that identifies specific material characteristics to conclude whether the product is free of hazardous chemicals or not. Models and calculations based on the data can then be developed to inform sustainable standards for the Circular Economy.

4.4.6 **Circular Economy Measures**

The rise in conversation on the CE has reached the point where we need to be measuring the impacts of a transition to it and the progress being made and possible future outcomes. Measuring progress towards a CE will involve much more detailed mapping of how resources move within the economy than there is now. Just as important are the economic impacts of the CE along value chains at company and sector level. Information technology initiatives is continuing to enhance the ability to track both resources and value flows, enabling companies to benefit from identifying wasteful processes along the supply chain and model new approaches. Measuring progress in the CE is challenging and what and how adopters of CE practices decide to measure will depend on their own objectives, scopes and audiences. Research conducted by the WBCSD found that 74% of their interviewees indicated that their company use their own framework for measuring circularity. Therefore, the cacophony of circular metrics popping up across sectors and geographies has created an environment of competing and often conflicting indications of actual circularity progress achieved (WBCSD, 2018).

Since the 1990's Product Service Systems (PSS) have been heralded as one of the most effective instruments for moving society toward a resource-efficient circular economy and creating a much-needed resource revolution. Tukker's paper reviews the literature on PSS over the last decade and compares the findings with those from an earlier review (Tukker, 2015). Tukker defines product service systems as a marketable set of products designed to meet the customer's needs. However, the paper extends this to identify resource efficiencies and circular economic concepts. The paper considers a large amount of reference papers on PSS. In the conclusion of this study there was no definite findings that PSS was more resource efficient but there were factors that would promote a circular economy and identifiable tools to support a CE framework. Product life spans of electric and electronic products are in decline, with detrimental environmental consequences. Tukker's research maps the environmental impacts of refrigerators and laptops against their increasing energy efficiency over time and finds that product life extension is the preferred strategy in both cases. Tukker then explores a range of product life extension strategies and concludes that tailored approaches are needed (Bakker, et al, 2014).

Product lifespans in our developed countries have steadily declined over the past decade, leading to an increased throughput of materials and therefore more waste. The negative environmental impacts of the increase in material use means the depletion of environmental resources is becoming critical. Plastics are a major concern and currently being widely reported in the news. Plastics are a major contributor to the pending solid waste crisis, representing almost 30% of the total waste when combined with rubber, leather, and textiles see Figure 4.10: Material Solid Waste.

A new CE standard would address these problems. Quantities of collected mobile phones in the UK can be analysed as part of a recycling program that contributes to circular economy activities.

There are five main reasons why business is interested in measuring their circularity:

To drive business performance strategy

To justify achievements externally

To integrate circularity across the business

To manage risk associated with the existing linear business model

To know the impact of their circular activities

(WBCSD, 2018)

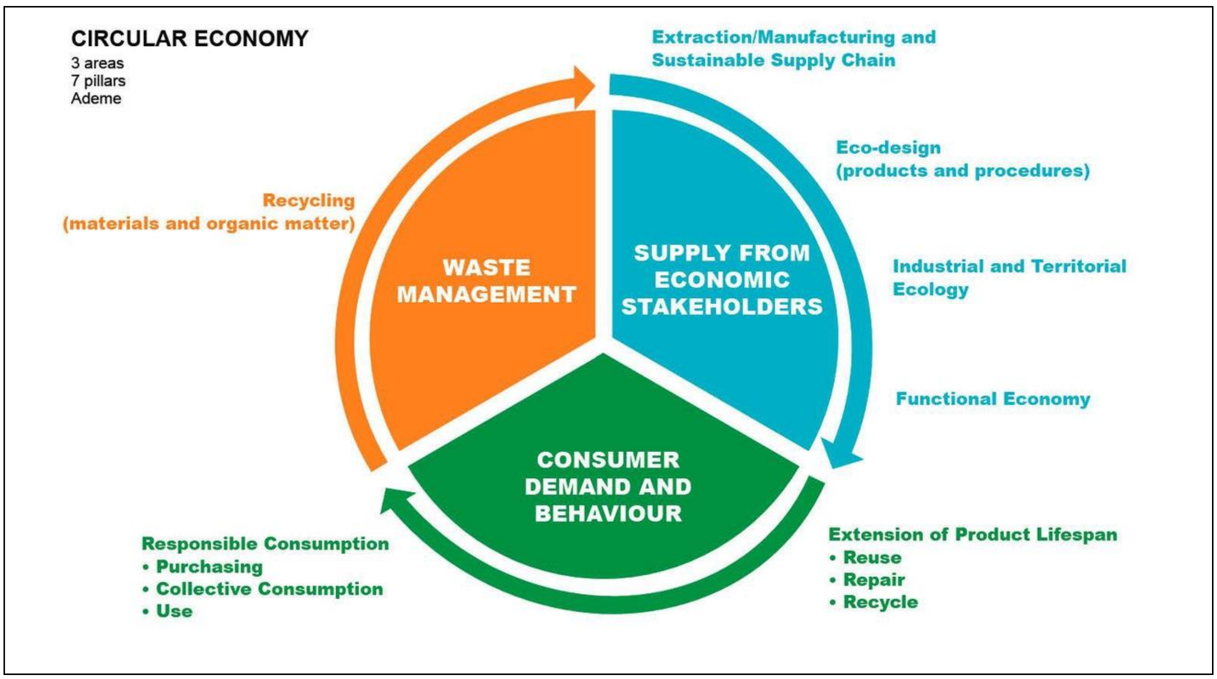


Figure 4.61: Contributing to Circular Economy Goals (Bonduelle, 2018)

The above Figure 4.61 has been taken from Bonduelle's contributions to the CE. They base these contributions on 3 main areas and 7 pillars.

<u>3 Main Areas</u>

Supply from Economic Stakeholders

Consumer Demand and Behaviour

Waste Management

7 Pillars for Action

Extraction/Manufacturing and Sustainable Supply Chain

Eco-design (products and procedures)

Industrial and Territorial Ecology

Functional Economy

Extension of Product Lifespan (Reuse, Repair, Recycle)

Responsible Consumption (Purchasing, Collective Consumption, use)

Recycling (materials and organic materials)

Figure 4.61 can be used (with some customization) by any organisation to contribute to the transition to the CE. It provides a framework that most businesses can adapt to and use.

4.4.6.1 **Ecological Footprint as a Measure**

Ecological footprint is already discussed in section 4.2.4, but not as a circular measure and having established the important contribution the ecological footprint makes to the circular economy it is necessary to highlight its measure here.

The most reported type of Ecological Footprint measures the biocapacity used to support a defined population's consumption. Unless otherwise specified, when you see Ecological Footprint values, they represent the footprint of consumption.

$$EF_{Production} + EF_{Imports} - EF_{Exports} = EF_{consumption}$$

The footprint of consumption (EF_C) is calculated from production and trade flows; it is the Ecological Footprint of all domestic economic production (EF_P, calculated as the footprint from local biocapacity and of all local carbon dioxide emissions), plus the footprint embodied in imports (EF_I), less the footprint embodied in exports (EF_E), (World Wildlife Fund, 2012).

4.4.6.2 **The European Green Deal**

The European Commission presented "The European Green Deal" (EGD), the most ambitious package of measures that should enable European citizens and businesses to benefit from a sustainable green transition.

Measures accompanied with an initial roadmap of key policies range from ambitiously cutting emissions, to investing in cutting edge research and innovation, to preserving Europe's natural environment, investing in green technologies, sustainable solutions and new businesses.

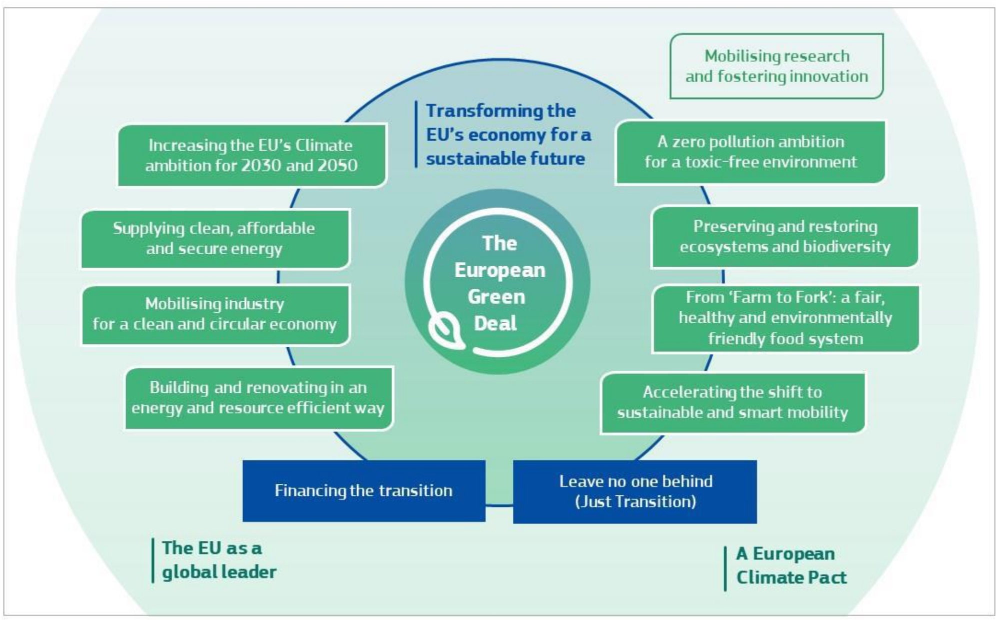


Figure 4.62: The European Green Deal (EGD, 2020)

The main Policy Areas of the EGD in Figure 4.62 are:

Clean Energy – opportunities for alternative, cleaner sources of energy

Sustainable Industry – ways to ensure more sustainable, more environmentally respectful production cycles

Building and Renovating – the need for a cleaner construction sector

Sustainable Mobility – promoting more sustainable means of transport

Biodiversity – measures to protect our fragile ecosystem

From Farm to Fork – ways to ensure more sustainable food systems

Eliminating Pollution – measures to cut pollution rapidly and efficiently

4.5 Case Studies

4.5.1 **Introduction**

Three case studies have been integrated in this report to further strengthen the methodological approach used in this thesis of a "mixed methodology". The case studies will analyse The Ellen MacArthur Foundation, The Circular Economy in China and Recycling Technologies Ltd.

4.5.2 **The Ellen MacArthur Foundation**

Dame Ellen MacArthur is a successful solo long-distance yachtswoman, who after retirement from sailing setup the Ellen MacArthur Foundation (EMF) in 2010 to accelerate the transition to the Circular Economy. Since its creation, the charity has emerged as a global thought leader, establishing the Circular Economy on the agenda of decision makers across business, government and academia (EMF4, 2012).

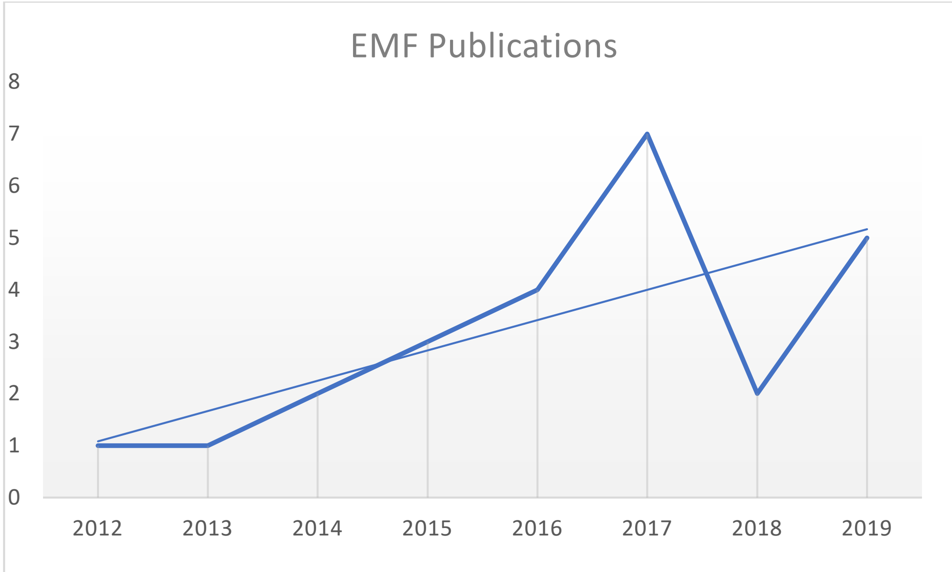
The Ellen MacArthur Foundation works in Education & Training, Business & Government, Insight & Analysis, Systemic Initiatives and Communications to accelerate the transition to a Circular Economy. The work of the Ellen MacArthur Foundation is important in this context. It has become a world leader in this relatively new field. The EMF's definition is probably the most used definition of the Circular Economy, every research paper tends to quote it. The EM Foundation defines the Circular Economy as: a systemic approach to economic development designed to benefit businesses, society and the environment. In contrast to the 'take-make-waste' linear model, a circular economy is regenerative by design and aims to gradually decouple growth from the consumption of finite resources (EMF4, 2012).

The EM Foundation's work focuses on six interlinking areas:

- Learning – developing the vision, skills and mindsets needed to transition to a Circular Economy
- Business – catalysing circular innovation and creating the conditions for it to reach scale
- Institutions, Governments and Cities - catalysing circular innovation and creating the conditions for it to reach scale
- Insight and Analysis – providing robust evidence about the benefits and implications of the transition
- Systemic Initiatives – transforming key materials flows to scale the Circular Economy globally
- Communications – engaging a global audience around the Circular Economy

(EMF4, 2012)

The foundation has published a range of publications on the Circular Economy including a book by Webster (2015) and a series of reports, listed in the Appendix Table 12: Ellen Macarthur Foundation Publications.



Qty	1	1	2	3	4	7	2	5
Date	2012	2013	2014	2015	2016	2017	2018	2019

Figure 4.63: EMF Publications

The publications from the EMF in Figure 4.63, show twenty-five in the last eight years is not substantive but they contribute enormously to the subject of the Circular Economy. In January 2012, the report published by the EMF i.e., Towards the Circular Economy Vol. 1 An economic and business rationale for an accelerated transition was the first of its kind in the world to consider the economic and business opportunities for transitioning to the circular economy. The graphical trend is that publications have increased generally year on year. More important is the fact that the CE is impacting or is being applied to more and more areas. This is reflected in and is the main reason for highlighting the EMF publications. As the environmental impacts especially of climate change and plastic waste are directly affecting economies and populations the urge to change this linear economy for a circular one becomes more prevalent. The earlier publications were all about laying down the definition, concept and principles of a CE, then as environmental impacts become more real the publications start to address areas such as consumer goods, global supply chains, circular business models and waste management. Later, in the last three years the publications have focussed on plastic waste, climate change, food waste and trying to highlight the need for this transition to the CE and what it will achieve economically and environmentally. The EMF publications have become a wealth of information on the CE and almost every research paper on the CE at some point cites a publication from the EMF.

4.5.3 The Circular Economy in China

For more than fifteen years, China's government has been a frontrunner on Circular Economy policies, with a focus on addressing pollution, promoting resource efficiency and industrial ecology. Building on these efforts, in 2017 the Chinese government introduced a new set of policies, centred on concepts such as product redesign, and the sharing economy, which highlight the innovation and value creation opportunities of a CE approach – particularly for Chinese cities.

Circular Economy Promotion Law of the PRC

The Circular Economy Promotion Law (CEPL) of the Peoples Republic of China was adopted at the 4th session of the Standing Committee of the 11th National People's Congress of the PRC on August 29th, 2008, and came into force on January 1st, 2009 (PRC, 2008).

The purpose of the circular economy law in China is to promote the development of the CE by improving the resource utilization efficiency, by protecting and improving the environment and realizing sustainable development. The CEPL focuses more on solid waste than on wastewater due to the intrinsic characteristics of the CE. The CE promotion law has gained political traction with national plans for safe urban municipal solid waste treatment, energy saving, and emissions reduction all based on CE principles.

In Article 3 of the CEPL, the Chinese Government commits to developing a State where the importance of the CE is strategized into overall plans, reasonable layouts, adjusting measures to local conditions and a focus on actual effect.

It is highly commendable that the Chinese Government has taken a top-down approach to the implementation of the CE in China. They declare that the development of a CE will be propelled by the Government, led by the market, effected by enterprises and participated in by the public. Government agencies are developing tax policies supporting resource recovery in industrial practices. Billions of dollars are being invested in CE oriented pilot projects, from applications of clean production techniques in specific sectors to municipal and regional eco-industrial development (Geng, 2013). In November 2016, the CEPL Amendment forum assessed the impact of the CEPL. There were some controversies around the legislative model and the functions of the law with some scholars believing that the CE in China is still going through a period of theoretical advocacy (Hu, et al, 2018).

The key laws and Regulations for Circular Economy implementation in China are summarised in the Appendix.

The Circular Economy Strategy in China

China has been a pioneer of standards at all levels: from national, to enterprise standards for individual companies and the country contributes substantially to the development of international standards. Standards are developed and mostly used as a voluntary document to facilitate whatever the user needs it for but in China, they can both underpin economic activity and be a more explicit part of the government's political leverage over other actors whether internal or external (Flynn, et al, 2019). The Circular Economy in China is a direct outcome of the national political strategy (top-down approach), and its implementation is structured following both a horizontal and a vertical approach. Chinese national governmental policy aims to transform not only the industry but also the socio-economic organisation of the society at all levels. The top-down approach of the Chinese national strategy is also reflected on the instruments used, that are mainly of command and control rather than market based (Ghilsellini, et.al, 2015).

The Chinese Circular Economy strategy is deployed at three levels:

- The enterprise-wide promotion of clean production,
- In industrial zones to implement industrial ecology [Eco-Industrial Parks i.e. – (EIP)]
- At regional level to develop Eco-cities.

This strategy was tested in seven industrial sectors and implemented in thirteen EIP's. Figure 4.64 below highlights the movement towards these EIP's as more industrial zones joins up each year except for 2002. In 2014 there was a sharp rise in joining's up by sixtyfour, this rise coincided with the introduction of the new Low-Carbon Industrial Park Program.

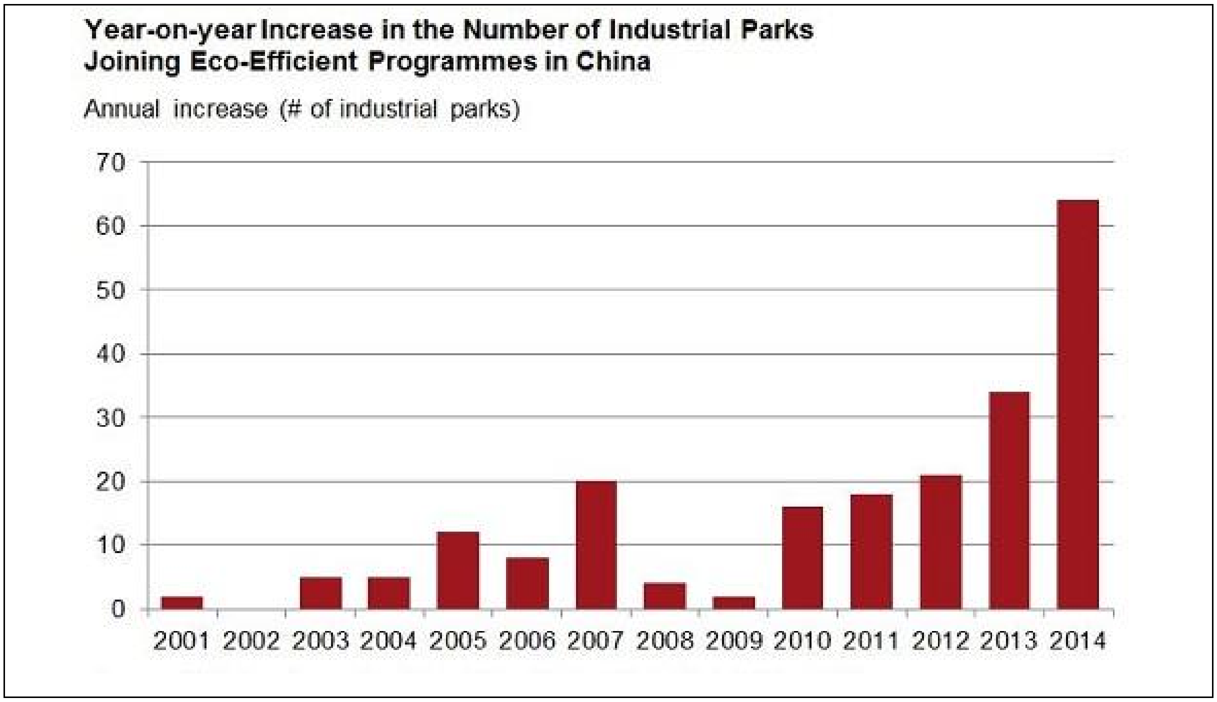


Figure 4.64: Eco-efficient Industrial Parks in China (source Thieriot and Sawyer, 2015)

Since 2005 testing has taken place in ten Eco-Cities and Eco Provinces – these are Beijing, Shanghai, Chongqing, Guiyang, Ningbo, Hebei, Tongling, Liaoning, Shandong, and Jiangsu – all under the leadership of the National Development and Reform Commission (Zhou, et al, 2014).

There are three main programs focused on the development of low-carbon industrial zones and EIP's. These programs are designed to motivate and help industrial parks to improve their environmental and economic performance. They are:

1. The Eco-Industrial Park Demonstration Program – the aim of the EIP is to minimize waste generation and improve the overall eco-efficiency of the park by applying principles such as those of industrial symbiosis, clean production, green supply chain management and centralized pollution abatement (Thieriot and Sawyer, 2015).

2. The Circular Transformation of Industrial Parks – the Circular Economy Pilot Zones (CEPZ) were initiated in 2001 by the Ministry of Environmental Protection (MEP). This section focusses on the industrial park level only, where the ultimate goal is to develop participating zones through a more circular economy pattern. (Thieriot and Sawyer, 2015).

Years	No of Zones
2005	13
2007	20
2011	8
2012	22
2013	20
2014	25

Figure 4.65: Two batches of Accredited Zones (redrawn – Thieriot and Sawyer, 2015)

Key: Demonstration pilot for the Circular Transformation of Industrial Parks (CTIP)

Circular Economy Pilot Zone (CEPZ)

Figure 4.65 shows the number of zones accredited since the programs began. In 2005 and 2007 the CEPZ program was in use while in the latter years it was the CTIP program. There were no added zones in the omitted years (e.g., 2006, 2008, 2009). Unlike the EIP program, the CTIP program is a direct source of national financing for the parks.

3. The Low-Carbon Industrial Park Program
   The Low-Carbon Industrial Park Program was launched in September 2013 aimed at accelerating China's movement towards low-carbon industries and increasing its industrial competitiveness by supporting innovation, upgrading technology and enhanced carbon management (Thieriot and Sawyer, 2015).

Table 13 in the Appendix is an expansive list of key indicators used by the Chinese to measure and calculate the results of the CEPL instituted in China. Key indicators are not a new concept they have been and still are widely used in manufacturing as Key Performance Indicators (KPI). Most of the indicators provide key measures needed to see how the law is progressing, like primary resource productivity being equal to GDP as an output with total consumption of natural resources being the inputs. There are several references to resource productivity to highlight its importance to the CE, it implies that natural resources are valued and therefore used in a conservative way to provide maximum efficiency. This equates to the natural resource utilization efficiency which represents the Economic, Social and Environmental (i.e., Sustainability) consequences generated by using measures of natural resources. Environmental Efficiency (EE) is another of those very important measures, efficiency simply means - the goal of achieving more with less. But more theoretically it can be defined as the product quantity (or output value or quantity of service) provided through unit environmental load (Hu, et al, 2018). Table 13 in the Appendix identifies several bulk resources i.e., petroleum, natural gas, coal, iron ore, non-ferrous metal ore, non-metallic resources and biomass resources, in consumption, these are the most common resources that should be measured.

Comparison of the Indicators

The different indicators are used to assess the environmental and economic performance of the industrial zones. Well-designed indicators are valuable for managing environmental development and providing guidelines to improve CE policies. Performance indicators for regions and industrial parks have been developed, based on well-known assessment methods: energy, material flow analysis (MFA), life cycle analysis (LCA)1, CO2 emissions and economic returns (Geng, 2013). These indicators can be divided into five categories:

- Land and population
- Material consumption
- Energy and emissions
- Pollution
- Administration and management

With the categories in place the zones can be piped against each other to see if there are any overlapping areas.

CE activity requires flows of materials, as in Figure 4.16 - Outline of a Circular Economy, these flows are within systems and organisations operations but with China these flows regularly operate between those countries/regions which produce waste and those countries whose supply chains can add further value to that material by making use of it within their processes, like China does. China has long been associated as a key trading partner for the West’s waste materials, having spent several decades processing the West’s waste into new resources (Flynn, et al, 2019). However, in January 2018 China enacted the “National Sword” policy, banning the import of most plastics and other materials from their recycling processors, which had handled almost half of the worlds recyclable waste. With rapid economic growth, the energy consumption rate has greatly increased in China. With greatly increased energy consumption comes increasing CO_2 emissions especially when using coal. China has become the largest developing country, the largest coal consuming country and the largest emitter of greenhouse gases (Yu, 2016). In 2012, China’s carbon emissions were almost equivalent to the carbon emissions of the USA and the EU-27 combined, see Figure 4.66. This graphic illustration of CO_2 emissions of Major emitters in Figure 4.66 is one output from the SINCERE project. In the near future, China will be faced with the formidable challenge of energy shortages. Conservation of energy will be crucial for

China's process industries. Based on the conditions in China, the government instituted the basic state policies of developing a circular economy (Li, et.al, 2007).

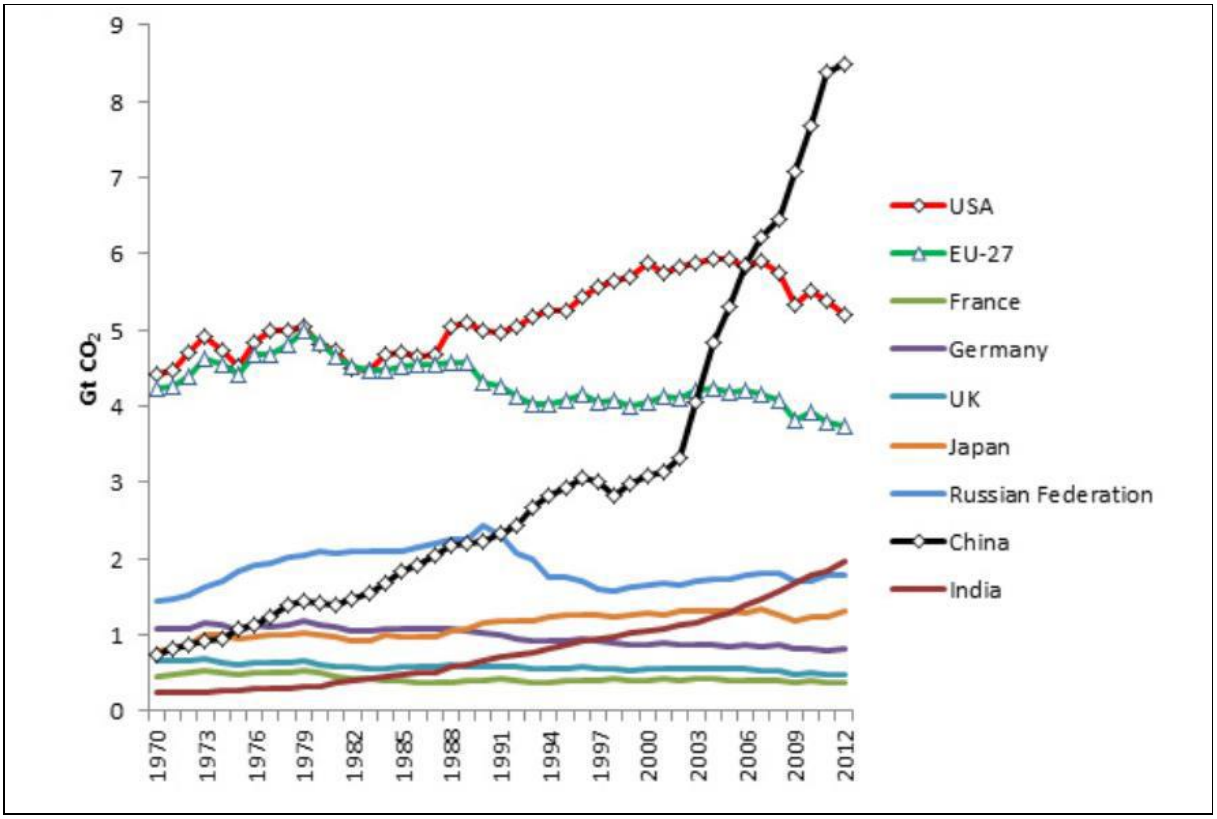


Figure 4.66: Total CO_2 emissions of Major emitters in 1970-2012 (Yu, 2016)

Circular Cities in China

The development of circular cities in China offers real potential in creating a Circular Economy. The rise in city living in China means they are uniquely positioned to accommodate transition to the CE, with high concentration of resources, capital, data and educated residents. A circular city embeds the principles of a CE across all its functions, establishing an urban system that is regenerative, accessible and abundant by design (EMF5, 2018). Driven by the digital revolution and a vibrant population, CE opportunities in China's cities have been identified in five focus areas, these are:

Built Environment

- Design for longevity
- Industrialise construction processes
- Share space to increase asset utilisation
- Improve energy efficiency through "green buildings"
- Enhance productivity with "smart buildings"
- Scale up reuse and recycling of construction and demolition waste

Mobility

- Facilitate multi-modal shared mobility
- Scale up remanufacturing and use more recycled materials
- Design vehicles to fit a circular mobility system
- Scale up zero emission forms of propulsion
- Encourage remote and flexible working

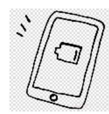
Nutrition

- Regenerate soil with urban food waste and wastewater
- Expand business models that promote effective agricultural supply chains
- Optimise food storage, transport and processing
- Design out loss and waste of food in the retail system
- Reinforce food consumption patterns beneficial to health and the environment

Textiles

- Scale up recycling 
- Pursue business models that increase utilisation of durable textiles
- Introduce resource efficiency measures

Electronics

- Encourage product-as-service 
- Reuse and refurbish products and remanufacture parts
- Capture the value of e-waste through recycling

(Redrawn - EMF5, 2018)

China has made serious efforts to the CE with the objective of providing long term and sustainable solutions to its severe resource scarcity and environmental deterioration problems. The CE was introduced as a new development model to surpass other countries to wholly subscribe to CE thinking and develop a more sustainable economic structure.

	Micro (single object)	Meso (symbioses association)	Macro (City, Province, State)
Production Area- Primary, Secondary and Tertiary industry	Cleaner production	Eco-industrial park	Regional eco-industrial network
	Eco-design	Eco-agricultural system	
Consumption area	Green purchase and consumption	Environmentally friendly park	Renting service

Waste management area	Product recycle system	Waste trade market	Urban symbiosis
		Venous industrial park	
Other	Policies and laws, Information platform, Capacity building, NGO's		

Table 14: Structure of the CE practices in China. (Adopted from Heshmati, 2005)

At the Micro level: eco-design, waste management and cleaner greener production become priorities at the organisational level. Cleaner greener production refers to minimal levels of emissions, while eco-design refers to combining environmental aspects in production processes and products that are efficient and sustainable through innovative designs and production lines.

At the Meso level: interactions among different firms or industries where each benefit from the by-products of one industry as raw resources for its own production and is analogous to ecological industry concepts. The application of this approach in China is facilitated by governmental directives that set out the terms of an eco-industrial district and subsidize its implementation, which is then reinforced by local leadership (Sauve, et al, 2015). At the Meso level eco-industrial parks have been initiated to allow companies to trade in industrial by-products i.e., waste trade market.

At the Macro level: activities include the development of eco-cities and eco-provinces or zones.

Figure 4.67: An overview of approved eco-industrial parks (EIP) in China (Ghisellini, et al, 2015)

China RoHS

The New China RoHS law – "Electrical and Electronic Products, Restriction of Hazardous Substances Management Measures" was published on January 6th, 2016, and became effective on 1st July 2016. It applies to the production, sale and import of Electrical and Electronic Products (EEP) within the territory of China. It is very similar to EU RoHS and restricts the same six substances [Lead, Mercury, Cadmium, Hexavalent Chromium, Polybrominated biphenyls (PBB) and Polybrominated diphenyl ethers (PBDE)]. They also kept the maximum concentration values tolerated in the homogeneous materials at 0.1%.

The product categories are like EU RoHS and products and parts that contain restricted substances exceeding limits can still be sold in China but need to be marked as such. The main difference, and it is a significant one between China RoHS and EU RoHS is that in China RoHS there are no exemptions, so it captures all EEP's. However, the products must be marked, a green mark affixed to the product indicates that the product complies with China RoHS and if the product contains substances above the China RoHS limits then a red sticker is affixed to the product displaying the environmental use period in the middle, see Figure 4.68 below.

Figure 4.68: China RoHS2 Marking (source: rohsguide, 2020)

Along with the non-compliance mark, a hazardous substance table must also be supplied with the product that lists each part that is out of compliance (rohsguide, 2020).

China REACH

In June 2010, the Ministry of Environmental Protection in China adopted the provisions on Environmental Regulations of new Chemical Substances, replacing a previous regulation from 2003. The 2010 regulations are like the EU's REACH but are known as China REACH.

4.5.4 **Recycling Technologies Ltd**

Recycling Technologies (RT) is a company setup to tackle a global environmental crisis, which is plastic waste. Ten years of research, engineering and collaboration with universities has progressed into a patented way of recycling plastic waste. RT's mission is to accelerate the evolution of plastic into a more sustainable material through innovation and technical excellence (RT, 2020).

The reason for case studying Recycling Technologies is to showcase the benefits of having a data centric standard for the CE by a real company. RT have declared that they live and breathe the ‘reduce, reuse, recycle mantra and believe that plastic is a great material and an integral part of the solution to reducing our carbon footprint (RT, 2020). RT understand the vision of the CE, their processes are changing the destructiveness of plastic waste into a valuable feedstock for new plastic production. Reversing plastic waste and the loss of valuable materials to landfill and incineration requires this transition from a linear to a CE for plastic. RT are converting low-grade plastic waste into feedstock by installing RT7000 machines at recycling centres around the world, each converting 7kt per annum of low-grade plastic waste into Plaxx. Plaxx is produced by the process of depolymerising plastic, resulting in a mixture of hydrocarbon-based monomers very similar to that found in crude oil as in Figure 4.69. Plaxx is a critical feedstock needed for a circular plastics economy (RT, 2020). The modular technology to recycle plastic waste into base chemicals, monomers and feedstocks can be duplicated at waste disposal or recycling centres anywhere in the world. Chemical recycling describes any technology that utilises processes or chemical agents that directly affect the chemistry of the polymers (BPF, 2021). These chemical recycling technologies fall into three main categories, shown in Figure 4.69.

These three categories are:

- Purification
- Depolymerisation
- Feedstock (thermal conversion) recycling

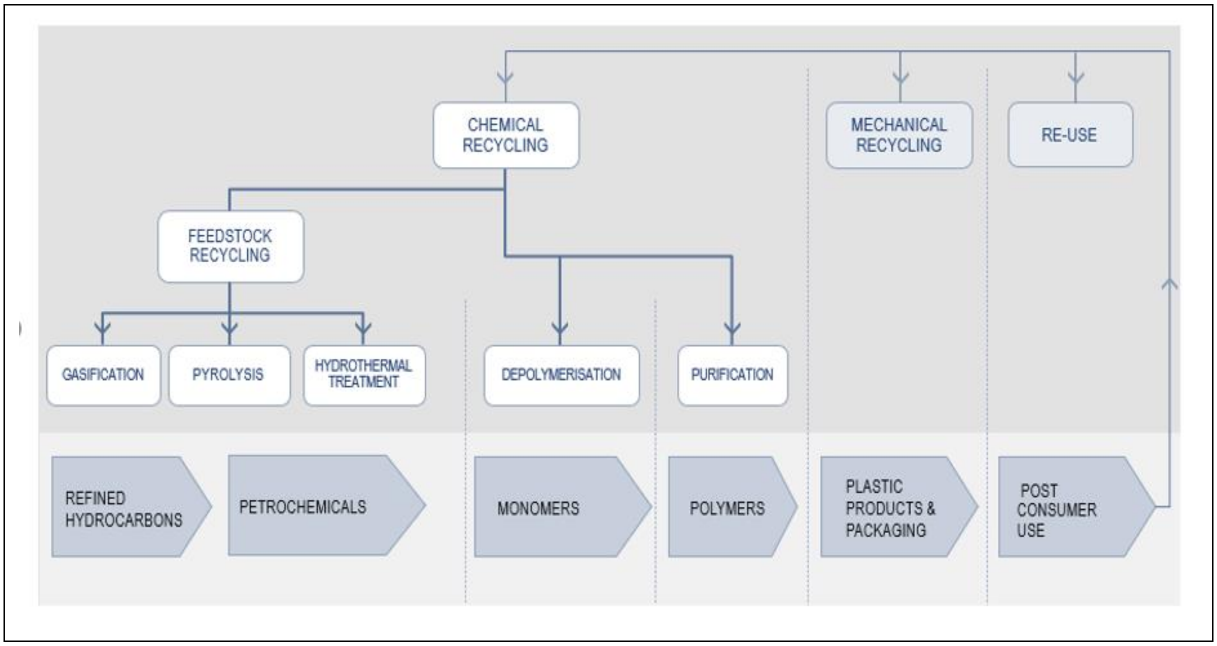


Figure 4.69: Processes to return recycled materials to the plastics supply chain (BPF, 2021)

The sustainability strategy of RT is also very admirable, by bridging the waste sector and the petrochemical industry they are enabling the creation of a CE where plastic can be continuously recycled (RT, 2020). The problem of plastics pollution has been well documented in our media and Figure 4.70 highlights this. The global plastic waste created is 5 million tonnes more than the global primary plastic production per year. This is clear evidence that doing nothing is not an option anymore and the situation is worsening because the world is using more resources than it is producing.

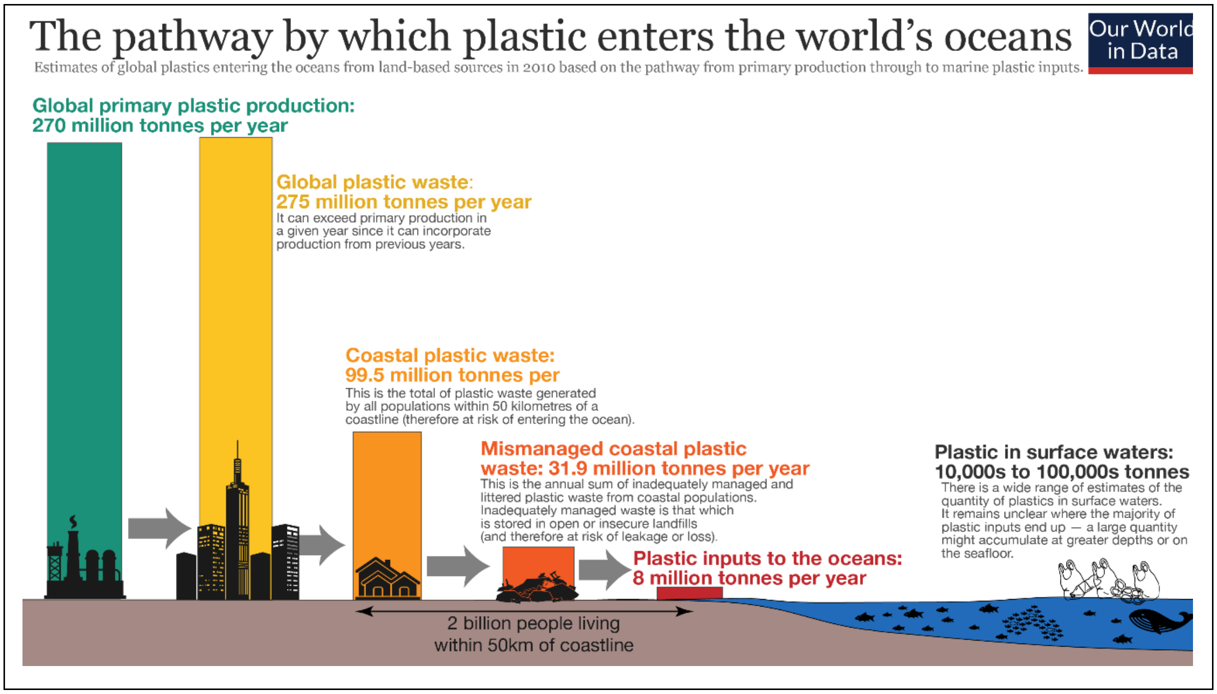


Figure 4.70: Plastic waste pollution (ourworldindata, 2018)

Recycling Technologies are at the forefront of doing something about the world's problems, but it has taken a long time to get where they are today. Their journey would have been shortened if there was a standard for the CE published for them to use, as it would contain the guidelines, models, research, data, how to and examples for RT to follow.

4.6 Framework Standard

4.6.1 **Introduction**

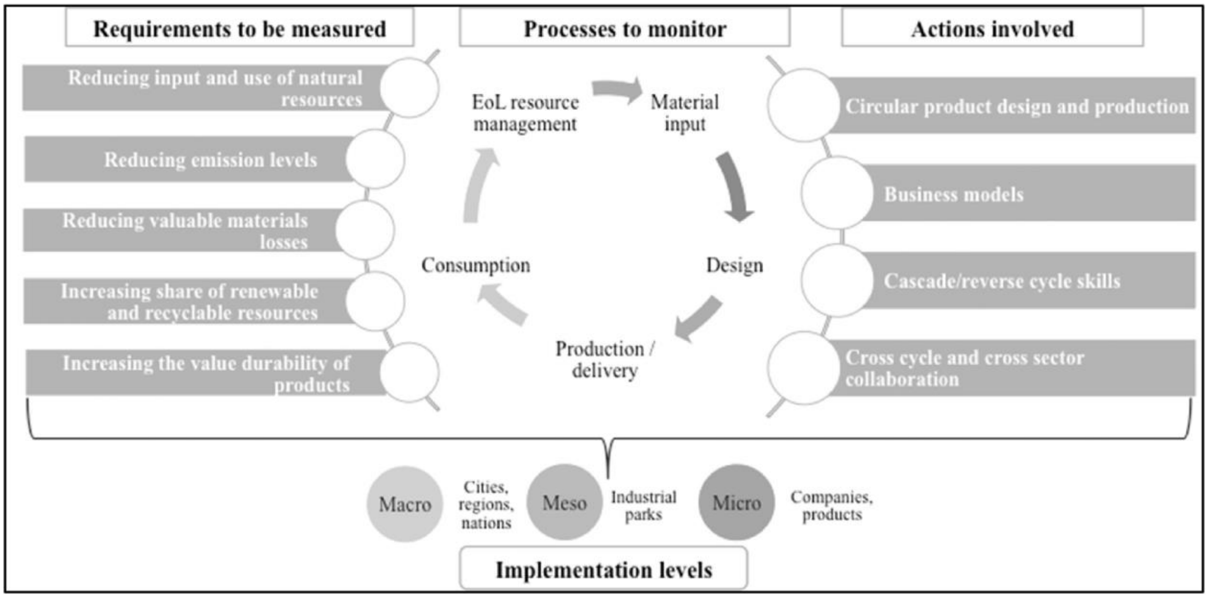


Figure 4.71: The Circular Economy Framework (Elia, et al, 2016)

The monitoring framework of the EC in the adopted report on the Implementation of the CE action plan shows progress has been made in four areas: production and consumption, waste management, secondary raw materials and competitiveness and innovation.

Within the circular economy framework in Figure 4.71 above (not necessarily covering all the components of this), a draft framework standard for the CE would help organisations to have a clear vision and reference for CE activities. The reasons for developing a Standard for the CE have already been addressed in Chapter 4.1, so this section will just draft a framework standard with elements/data from other chapters. A key part of developing standards is the collaboration of individual experts from differing backgrounds, cultures, races etc all combining to find consensus to develop a coherent standard. However, as an individual thesis this element of developing a standard will be replaced by the outcomes of the literature review and the thesis writer will decide which elements are in the draft framework.

4.6.2 **Framework**

FOREWORD

INTRODUCTION

1. Scope
2. Normative References
3. Terms and Definitions
4. Context of the Circular Economy for Organisations
   - 4.1 Scope for a Management System Standard for the CE
   - 4.2 Contribution of the Circular Economy to the Sustainable Development Goals
   - 4.3 Digital Technologies (Data Science, RFID, IoT, AI)
   - 4.4 Principles of the Circular Economy
     - 4.4.1 General (Circular economy models)
     - 4.4.2 Issues of the Circular Economy (critical raw materials, ozone depleting substances, population increase, resource efficiency etc)
     - 4.4.3 Sustainable supply chains (use of Reverse Logistics)
     - 4.4.4 Circular ecology (systems thinking, ecological foot-printing)
     - 4.4.5 Eco-design (legislation/standards, innovation, product design)
     - 4.4.6 Sustainable consumption and Production (SDG's)
     - 4.4.7 Life cycle analysis
     - 4.4.8 Waste management (legislation)
5. Leadership
   - 5.1 General (organisation)
   - 5.2 Circular Economy policy (commitment, ethics)
   - 5.3 Organisation roles and responsibilities (top-down approach)
6. Planning
   - 6.1 General
   - 6.2 Risk Assessment
   - 6.3 Objectives of the CE projects and plans to achieve them
   - 6.4 Sustainable Finance

7. Operational Planning and Control

    7.1 General (Plan-Do-Check-Act)

    7.2 Conformity (ensure compliance with the strategy, programs, plans etc)

8. Implementation of the Standard

    8.1 General

    8.2 Initial assessment

    8.3 Action plan

    8.4 Monitoring, reporting and verification of results

    8.5 Performance evaluation

9. Supporting Functions

    9.1 General

    9.2 Resources

    9.3 Competence (training, training records)

    9.4 Awareness

    9.5 Communication

        9.5.1 Documented information

        9.5.2 Maintenance and control of documented information

10. Performance Evaluation

    10.1 General

    10.2 Monitoring (CE measures, KPI's, data analysis and evaluation)

    10.3 Auditing (internal/external audits, non-conformity, corrective actions)

    10.4 Management Review (annually)

    10.5 Continual Improvement (future innovation)

11. Annexes (use cases, examples)

4.7 **Conclusion**

There is no denying the fact, that the world has grown, in the size of the population and in economic terms. This of itself is not surprising, its naturally expected that as the population grows so will the economic requirements grow to provide for the needs of the population. What has surprised us is the massive increase in consumption beyond what is needed, the excessive use of resources and the production of waste everywhere. Resource price fluctuations, mainly increasing and the volatility of resources availability have occurred almost simultaneously. Instead of continuing the linear economy, the transition towards a Circular Economy (addressed in Chapter 4.1) is widely considered and proven here to be an essential step to counter these problems and to change mindsets to the kind of Sustainable Development Goals that meet the needs of the present generation without compromising the ability for future generations to meet their own needs. This will require a transformation of how we produce and consume, collaborate, and tender businesses by closing the loops at the highest possible level. It will also require the cultivation of a Circular Economy mindset in consumers to whom consumerism has become too established. With continued interest in the Circular Economy reactions in Europe and around the world is increasingly positive as countries and organisations realise doing nothing is not an option.

For the transition to the Circular Economy to become the norm, it is essential that there are commonly accepted arguments or like in standards development, consensus on how it is to be done i.e., frameworks, principles, common terminology, business models. As everything we do is impacted by standards knowingly or unknowingly and our lives are driven by data and analysis of data. Luxembourg recently launched a project "Circularity Dataset Initiative" to address the difficulty for industry to provide reliable data on different circular product properties. The lack of a European or International Standard on the Circular Economy forces manufacturers and other organisations to report on CE issues in differing ways sometimes unhelpful and inaccurately, sending out confusing messages to consumers. A CE standard would correct that. One of the main concerns of this thesis is the management of hazardous chemicals and a large section of Chapter 4.1 covers this. The transition to a CE will continue to manage hazardous chemicals and elevate further to promote consumer purchase and use of non-toxic products and better tracking of chemicals of concern to facilitate the recycling and consumption of secondary materials.

At the start of this thesis, the proposed research was to present the information and data analysis that can be applied to the development of standards for the Circular Economy – this could have concluded in a framework standard; it may have concluded in a submitted New Work Item Proposal (NWIP) or it may have concluded in a Publicly Available Specification (PAS), it has concluded in a Framework that can be developed into a National, European or International Standard on the CE. The mixed methodology approach meant that data was drawn from structured, semi-structured and unstructured data sources. The underlying data from making products that are sourced sustainably, are REACH compliant, are traceable through RFID tagging, means this research can use this data, both quantitative and qualitative to inform the standards development process. In May of 2021, the IEC agreed to progress with a new standard to address e-waste. Among its objectives it seeks to reduce the amount of e-waste sent for disposal through reuse and recovery, prevent the inappropriate disposal of e-waste and restrict operators who do not comply with the standard or comparable requirements from receiving e-waste shipments. It is a start, but it does not go deep enough, however it underlines the need and usefulness of standards.

Although there were Circular Economy related activities in China before the 2009 enacted Circular Economy Promotion Law, CEPL really accelerated China's transitioning towards the CE. With the CEPL becoming the Chinese national strategy for achieving a CE, this strategy is unique to China across the world. China's socioeconomic environment provides a context different from other nations, making it an ideal laboratory for new, expanded CE policies (Geng, et al, 2013)

Man-made emissions of CO_2 and other greenhouse gases contribute enormously to climate change and is seen as one of the most pressing challenges of this generation. This challenge has not only forced countries to reduce their greenhouse gas emissions but also to innovate better ways of production and consumption and the Circular Economy fits those criteria. The Ellen MacArthur foundation brings a charitable venture that is passionate about motivating organisations to transition to the CE and providing the resources to do it.

The case study on the Ellen MacArthur foundation revealed the enormity of the influence they have on the CE with regular publications, courses on the CE and a vibrant presence on social media, digital platforms (website, webinars client engagement). The Chinese prefer to use the long arm of the law to achieve their goal of a CE but have something special in their eco-efficient Industrial Parks.

Recycling Technologies have highlighted the need for a CE standard by alluding to the years of research and collaborations it has taken to achieve their current position. Also, the fact that a well-developed standard can be instrumental in solving critical world problems. This thought is echoed in countries and governments now encouraging/asking their national standards body to develop standards that can be used to address environmental, economic and societal problems.

Legislation, regulation, and policy determinants influence and motivate consumers' and suppliers' environmental practices, paving the way towards Circular Economy implementation. In the case of consumer behaviour policy makers may propose instruments to decrease resource demand, such as incentives for smaller dwellings, repairing or renovating products (including electronics) instead of purchasing new ones, and encouraging a sharing economy. Moreover legislation, regulation and policy determinants should support the development of innovative solutions for waste collection (Prieto-Sandoval, 2017). Highlights on Europe's reaction to the CE is dictated by the literature available. The focus has been on the REACH regulation as understanding its requirements is key to the use of materials in a Circular Economy. The importance of the REACH regulation is key to the concept of the CE, by designing out waste, being able to trace materials and substances and using the SCIP database to make the data accessible. The SCIP database will require the use of data science tools and the fact that most European countries are willing to pull in the same direction, consensus on a data-centric Standards for the CE would be highly likely. The problems of the current linear systems are not new, the sit back and watch approach has become too risky. So, action is needed. Organisations are acknowledging that the linear system increases their exposure to increasing costs of purchasing raw materials, environmental costs of climate change – flash flooding, persistent fires and extreme weather conditions. All this contributes to the erosion of our natural ecosystems. The transition to a CE will only be achieved through circular and technological business models, digital technologies and enabling strategies that complements and organizes these systems. One of these key enablers is the development of a Standard for the CE. A standard is needed to consolidate best practices, consensus from different continents around the world, analysis of the relevant data and the circular economy being incorporated into a proven system where new technology is reviewed.

Paring the digital revolution with the principles of a circular economy model has the potential to radically transform the industrial landscape and its relationship to materials and finite resources, thus unlocking additional value for the manufacturing sector (Charnley, et al, 2019). Gathering original data from a DM product adds practicality on how digital technologies (i.e., RFID) can be used to facilitate information to use in developing a standard for the CE. The role of diversity in the CE removes any restrictions that might surface, because understanding how the CE operates at the various levels encapsulates how it affects the creation of value, management, technological advances, decision-making processes, leadership and the culture of an organisation is of utmost importance.

Chapter 4.3 has sought to take the Financial Economy and the Circular Economy and take their core concepts to see if there is any conflict. Without the research the logical thoughts would be that the financial and circular economies will complement each other, they both need each other to be successful. In the main this is the case; you just cannot have a successful circular economy without investing in it. You can see from the research paper of Mr Ongondo that there are quite a few barriers, and they are not confined to costs. Organisations face two main challenges in implementing the circular economy, firstly people must be educated of the fact that the products created through the circular economy are new products not second-hand ones. They are fully functional products that are guaranteed to be serviced and repaired if they are in use albeit at a much-reduced price. Secondly, societal status and personal self-esteem influence the products some people purchase, Table 10 refers to this as the lack of confidence in refurbished equipment and so the circular economy is faced with the difficult task of changing the very concept of ownership. However, this could be easily overcome if the trend setters and brand masters were also playing their part in the circular economy. Several barriers that remain to unlock are beginning to be unlocked like the availability of data.

Data on the financial contributions, funding and future spend on CE projects have cemented the fact that a sustainable standard is needed to guide future generations to taking advantage of the benefits the Circular Economy brings. The subject of the Circular Economy is just beginning to take root in our societies as an alternative to managing the massive amounts of waste we are producing, but unless we accelerate this transition, we will continue to suffer the consequences.

The future of the Circular Economy is showing more and more organizations its potential for managing risks, reducing costs, reducing waste and increasing revenues. This is evident in many European countries and a lot more could have been said as countries in Europe and across the World draw up roadmaps and plans to transition to the CE. Chapter 4.4 researched climate change, eco-design, research and innovation, sustainable development goals and CE measures. All these areas are increasing their application to the CE and all of them require data science tools to realize their full potential.

Data science will become increasingly important to the CE as the digital age takes over and the world becomes accustomed to using data analysis to inform sustainable standards for everything. By presenting the relevant data on the "Circular Economy" (using data analysis tools) there is more meaning, more belief, more reality to developing sustainable standards for the Circular Economy, without it the gap for European, and International standards on the Circular Economy continues.

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APPENDIX

Chapter 1: Introduction

Chapter 2: Literature Review

A list of these twenty critical raw materials recycling rates.

Raw materials	Main producers (2010, 2011, 2012)	Main sources of imports into the EU (mainly 2012)	Substitutability index*	End-of-life recycling input rate**
Antimony (Stibium)	China 86 %	China 92% (unwrought and powdered)	0.62	11%
	Bolivia 3 %	Vietnam (unwrought and powdered) 3 %		
	Tajikistan 3 %	Kyrgyzstan 2% (unwrought and powdered); Russia 2% (unwrought and powdered)		
Beryllium	USA 90 %	USA, China and Mozambique4	0.85	19 %
	China 9 %			
	Mozambique 1 %			
Borates	Turkey 41 %	Turkey 98 % (natural borates) and 86 % (refined borates)	0.88	0 %

	USA 33 %	USA 6%, Peru 2% (refined borates); Argentina 2% (natural borates)		
Chromium	South Africa 43 %	South Africa 80 %	0.96	13%
	Kazakhstan 20 %	Turkey 16 %		
	India 13 %	Others 4 %		
Cobalt (Cobaltum)	DRC 56 % ↑	Russia 96 % (cobalt ores And concentrates)	0.71	16 %
	China 6%; Russia 6%;	USA 3 % (cobalt ores and concentrates)		
	Zambia 6 %			
Coking coal	China 53 %	USA 41 %	0.68	0 %
	Australia 18 %	Australia 37 %		
	Russia 8%; USA 8 %	Russia 9 %		
Fluorspar (Fluorite)	China 56 %	Mexico 48 % ↑	0.80	0 %
	Mexico 18 %	China 13 % ↓		
	Mongolia 7 %	South Africa 12 % ↓		
Gallium	China 69 % (refined)	USA 49 %	0.60	0 %
	Germany 10 % (refined)	China 39 %		
	Kazakhstan 6 % (refined)	Hong Kong 8 %		
Germanium	China 59 % ↓	China 47 % ↓	0.86	0 %

	Canada 17 %	USA 35 %		
	USA 15 %	Russia 14 %		
Indium	China 58 %	China 24 % ↓	0.82	0 %
	Japan 10 %	Hong Kong 19 % ↑		
	Korea 10 %	Canada 13 %		
	Canada 10 %	Japan 11 %		
Magnesite	China 69 %	Turkey 91 %	0.72	0 %
	Russia 6%; Slovakia 6 %	China 8 %		
Magnesium	China 86 % ↑	China 91 % ↓	0.64	14%
	Russia 5 %	Israel 5 %		
	Israel 4 %	Russia 2 %		
Natural graphite	China 68 %	China 57 % ↓	0.72	0%
	India 14 %	Brazil 15 %		
	Brazil 7 %	Norway 9 %		
Niobium	Brazil 92 %	Brazil 86 % (Ferro-Niobium)	0.69	11%
	Canada 7 %	Canada 14 % (Ferro-Niobium)		
Phosphate rock	China 38 %	Morocco 33%	0.98	0%
	USA 17 %	Algeria 13%		
	Morocco 15 %	Russia 11%		
Platinum Group Metals	South Africa 61 % ↓	South Africa 32 % ↓	0.83	35%
	Russia 27 % ↑	USA, 22 % ↑		

	Zimbabwe 5 %	Russia 19 % ↓		
Heavy Rare Earth Elements	China 99 %	China 41 % (all REEs)	0.77	0%
	Australia 1 %	Russia 35 % (all REEs)		
Light Rare Earth Elements	China 87 %	USA 17 % (all REEs)	0.67	0%
	USA 7 %			
	Australia 3 %			
Silicon metal (Silicium)	China 56 %	Norway 38 %	0.81	0%
	Brazil 11 %	Brazil 24 %		
	USA 8%; Norway 8 %	China 8 %		
	France 6 %	Russia 7 %		
Tungsten (Wolframium)	China 85 %	Russia 98 %↑	0.70	37%
	Russia 4 %	Bolivia 2 %		
	Bolivia 2 %			

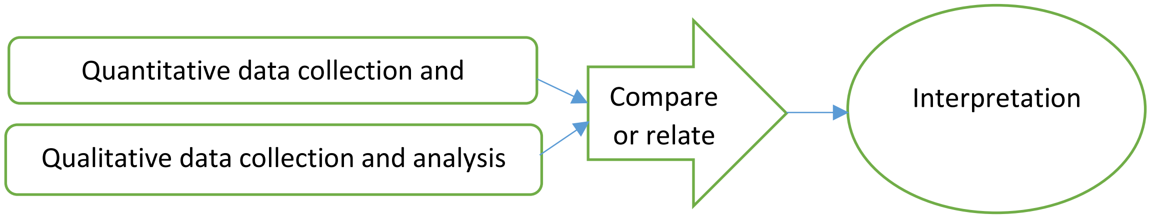
Chapter 3: Methodology

1. Triangulation Design:

* Researcher uses concurrent timing to implement quantitative and qualitative strands

* Researcher prioritises strands equally and keeps them independent during analysis

* The researcher mixes the results of the two strands during final interpretation



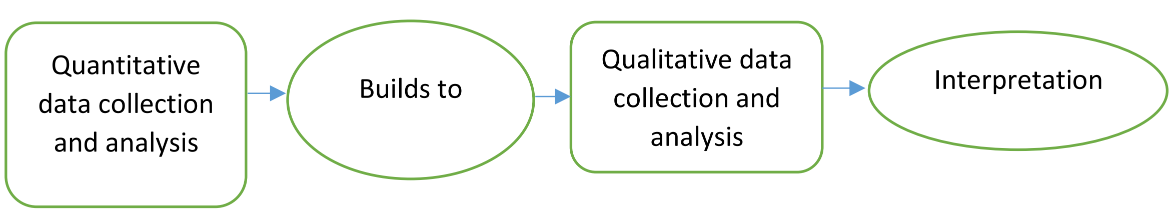
2. Explanatory Sequential Design:

* Researcher implements two distinct interactive phases of quantitative and qualitative work

* The first phase of the research consists of quantitative data collection and analysis

* Researcher interprets the secondary qualitative results to help explain the initial quantitative results

* The priority can be placed on either the qualitative or quantitative phase



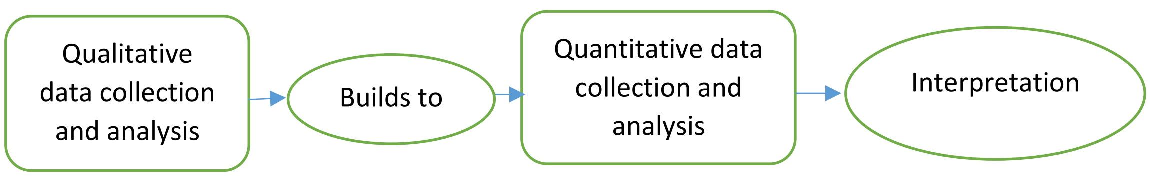
3. Exploratory Sequential Design:

* Researcher implements two distinct interactive phases of quantitative and qualitative work

* The first phase of the research consists of qualitative data collection and analysis

* The researcher conducts a second quantitative phase to test or generalise the initial qualitative findings

* The priority can be placed on either the qualitative or quantitative phase



4. Embedded Design:

* The Researcher collects and analyses both quantitative and qualitative data within a traditional design, adding a supplemental qualitative strand to a quantitative design or a quantitative design to a qualitative design

* The supplemental strand is added to enhance the overall design of the research

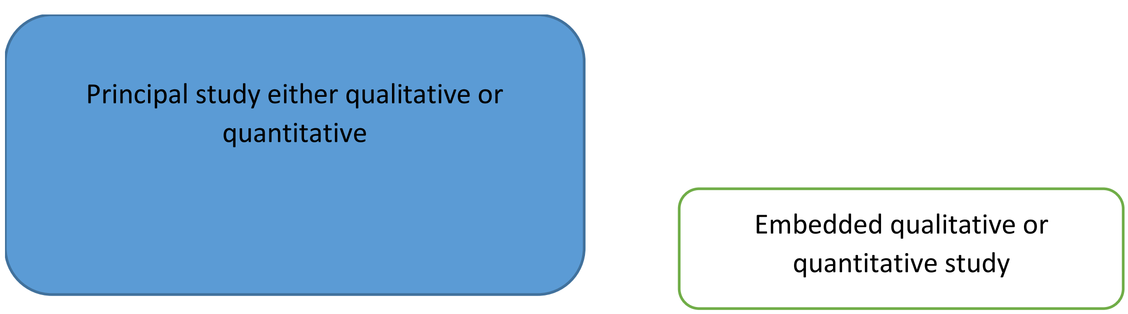


Figure 3.1: Four primary categories of mixed-methods research design (Pringle, 2017)

There are four major categories of mixed method research design:

- Triangulation Design – is the most common and well-known approach for mixing methods, its purpose is to “obtain different but complementary data on the same topic” (Morse, 1991)
  The intention of this type of mixed method design is to bring together non-overlapping strengths and weaknesses from a range of quantitative methods with those of qualitative methods. When researchers want to compare and contrast qualitative data with quantitative data -this method is used.
- Explanatory Sequential Design – is a two-stage mixed methods design in which initial quantitative results are built upon by qualitative data. This type of research design is helpful to explain significant, surprising or outlying quantitative results by providing extra qualitative data.
- Exploratory Sequential Design – is similar to the explanatory sequential design method, in that they both use the results of the first phase to help develop the second phase – i.e. the results from the qualitative phase contributes to develop the second qualitative phase. This design is best used to explore a phenomenon, where exploration is needed because measures of instruments are not available, and variables are unknown.
- Embedded Design – is a study based primarily on one data type being supported by another data type that plays a secondary role. The observation here is that one data type is not enough to answer all the research questions and that another data type is required. In research that is largely quantitative, qualitative data will provide support and the reverse is also true.

See the diagram for this in the Appendix (Figure 3.1). Each type of design has different characteristics and performs different functions, with different types of data to be collected (Creswell, 2014).

Chapter 4: Research Findings and Analysis

No	Source	Description	Chapter	Format
		QUANTITATIVE DATA		
	Internet search	Search results for the Circular Economy	Lit Review	Word pdf
1	http://www.namibiarareearths.com/market-demand.asp	Materials being depleted from the Environment	1	Excel Spreadsheet
2	WasteDataFlow, DEFRA https://www.gov.uk/government/statistical-data-sets/env23-uk-waste-data-and-management	Waste from Households	1	Excel Spreadsheet
3	WasteDataFlow, DEFRA	Takeback schemes for Recycling	4	Excel Spreadsheet
4	http://www.envfor.nic.in/legis/ods/odssch1.html	Ozone-Depleting Substances	1	Table word doc
5	BGS – Platinum 2009	Applications of Platinum	1	Excel Spreadsheet
6	Eurostat (env_wasmun)	Municipal waste treatment methods and waste per capita in the EU-28 (2014)	1	Excel Spreadsheet
7		World population growth	1	Excel Spreadsheet
8		Adoption of Standards	1	Excel Spreadsheet

9	Eurostsat 2015	Municipal Solid Waste treatment in selected EU countries	2	Excel Spreadsheet
10	ECHA Website	Substances of Very High Concern (SVHC)	2	Excel Spreadsheet
11	ECHA Website	Countries submitting Dossiers for the "Candidate List"	2	Excel Spreadsheet
12		Ecological Footprint Data Table	3	Excel Spreadsheet
13	ECHA Website	Climate related extremes in the EU	5	Excel Spreadsheet
14		Horizon 2020 Applications	5	R script
		QUALITATIVE DATA		
	REACH Regulation	REACH EU word cloud	2	R script
1	Ellen MacArthur Foundation website Various other websites and peer reviewed research papers	Proposed Case Study on Ellen MacArthur Foundation and the CE	6	Pdf Word Excel
2	Various websites and peer reviewed research papers	Proposed Case Study on China and the CE	6	Pdf Word Excel
3	Various websites and peer reviewed research papers	List of Research Papers	Appendix	Excel

Table 1: Data scoping Table

List of Ozone-Depleting Substances

S.No.	Name of Ozone Depleting Substance	Chemical Composition of Ozone Depleting Substance	Group	Ozone Depleting Potential
1	**-2**	**-3**	**-4**	**-5**
1	CFC-11	Trichlorofluoromethane ($CFCl_3$)	I	1
2	CFC-12	Dichlorodifluoromethane (CF_2Cl_2)	I	1
3	CFC-113	Trichlorotrifluoroethane ($C_2F_3Cl_3$)	I	0.8
4	CFC-114	Dichlorotetrafluoroethane ($C_2F_4Cl_2$)	I	1
5	CFC-115	Chloropentafluoroethane (C_2F_5Cl)	I	0.6
6	Halon-1211	Bromochlorodifluoromethane (CF_2BrCl)	II	3
7	Halon-1301	Bromotrifluoromethane (CF_3Br)	II	10
8	Halon-2402	Dibromotetrafluoroethane ($C_2F_4Br_2$)	II	6
9	CFC-13	Chlorotrifluoromethane (CF_3Cl)	III	1
10	CFC-111	Pentachlorofluoroethane (C_2FCl_5)	III	1
11	CFC-112	Tetrachlordifluoroethane ($C_2F_2Cl_4$)	III	1
12	CFC-211	Heptachlorofluoropropane (C_3FCl_7)	III	1
13	CFC-212	Hexachlorodifluoropropane	III	1

		($C_3F_2Cl_6$)		
14	CFC-213	Pentachlorotrifluoropropane ($C_3F_3C_5$)	III	1
15	CFC-214	Tetrachlorotetrafluoropropane ($C_3F_4Cl_4$)	III	1
16	CFC-215	Trichloropentafluoropropane ($C_3F_5Cl_3$)	III	1
17	CFC-216	Dichlorophexafluoropropane ($C_3F_6Cl_2$)	III	1
18	CFC-217	Chloroheptafluoropropane (C_3F_7Cl)	III	1
19	Carbon tetrachloride	Tetrachloromethane (CCl_4)	IV	1.1
20	Methyl chloroform	1, 1, 1-Trichloroethane ($C_2H_3Cl_3$)	V	0.1
21	HCFC-21	Dichlorofluoromethane ($CHFCl_2$)	VI	0.04
22	HCFC-22	Dichlorodifluoromethane (CHF_2Cl)	VI	0.055
23	HCFC-31	Chlorofluoromethane (CH_2FCl)	VI	0.02
24	HCFC-121	Tetrachlorodifluoroethane ($C_2HF_2Cl_4$)	VI	0.04
25	HCFC-122	Trichlorodifluoroethane ($C_2HF_2Cl_3$)	VI	0.08
26	HCFC-123	2, 2-dichloro-1, 1, 1-trifluoroethane ($C_2HF_3Cl_2$)	VI	0.06
27	HCFC-123a	1.2-dichloro-1, 1, 2-trifluoroethane	VI	0.02

		($CHCl_2CF_3$)		
28	HCFC-124	2-chloro-1, 1, 1, 2-trifluoroethane (C_2HF_4Cl)	VI	0.04
29	HCFC-124a	2-chloro-1, 1, 2, 2-trifluoroethane ($CHFClCF_3$)	VI	0.022
30	HCFC-131	Trichlorofluoroethane ($C_2H_2FCl_3$)	VI	0.05
31	HCFC-132	Dichlorodifluoroethane ($C_2H_2F_2Cl_2$)	VI	0.05
32	HCFC-133	Chlorotrifluoroethane ($C_2H_3F_3Cl$)	VI	0.06
33	HCFC-141	Dichlorofluoroethane ($C_2H_3FCl_2$)	VI	0.07
34	HCFC-141b	1, 1-dichloro-1-fluoroethane (CH_3CFCl_2)	VI	0.11
35	HCFC-142	Chlorodifluoroethane ($C_2H_3F_2Cl$)	VI	0.07
36	HCFC-142b	1-chloro-1, 1-difluoroethane (CH_3CF_2Cl)	VI	0.065
37	HCFC-151	Chlorofluoroethane (C_2H_4FCl)	VI	0.005
38	HCFC-221	Hexachlorofluoropropane (C_3HFCl_6)	VI	0.07
39	HCFC-222	Pentachlorodifluoropropane ($C_3HF_2Cl_5$)	VI	0.09
40	HCFC-223	Tetrachlorotrifluoropropane ($C_3HF_3Cl_4$)	VI	0.08
41	HCFC-224	Trichlorotetrafluoropropane ($C_3HF_4Cl_3$)	VI	0.09

42	HCFC-225	Dichloropentafluoropropane ($C_3HF_5Cl_2$)	VI	0.07
43	HCFC-225ca	1, 3-dichloro-1,2, 2,3,3-pentafluoropropane ($CF_3CF_2CHCl_2$)	VI	0.025
44	HCFC-225cb	1-3-dichloro-1,2,2,3,3-pentafluoropropane (CF_2ClCF_2CHClF)	VI	0.033
45	HCFC-226	Chlorohexafluoropropane (C_3HF_6Cl)	VI	0.1
46	HCFC-231	Pentachlorofluoropropane ($C_3H_2FCl_5$)	VI	0.09
47	HCFC-232	Tetrachlorodifluoropropane ($C_3H_2F_2Cl_4$)	VI	0.1
48	HCFC-233	Trichlorotrifluoropropane ($C_3H_2F_3Cl_3$)	VI	0.23
49	HCFC-234	Dichlorotetrafluoropropane ($C_3H_2F_4Cl_2$)	VI	0.28
50	HCFC-235	Chloropentafluoropropane ($C_3H_2F_5Cl$)	VI	0.52
51	HCFC-241	Tetrachlorofluoropropane ($C_3H_3FCl_4$)	VI	0.09
52	HCFC-242	Trichlorodifluoropropane ($C_3H_3F_2Cl_3$)	VI	0.13
53	HCFC-243	Dichlorotrifluoropropane ($C_3H_3F_3Cl_2$)	VI	0.12
54	HCFC-244	Chlorotetrafluoropropane ($C_3H_3F_4Cl$)	VI	0.14
55	HCFC-251	Trichlorofluoropropane ($C_3H_4FCl_3$)	VI	0.01
56	HCFC-252	Dichlorodifluoropropane	VI	0.04

		$(C_3H_4F_2Cl_2)$		
57	HCFC-253	Chlorotrifluropropane $(C_3H_4F_3Cl)$	VI	0.03
58	HCFC-261	Dichlorofluoropropane $(C_3H_5FCl_2)$	VI	0.02
59	HCFC-262	Chlorodifluoropropane $(C_3H_5F_2Cl)$	VI	0.02
60	HCFC-271	Chlorofluoropropane (C_3H_6FCl)	VI	0.03
61	BFC-21B2	Dibromofluoromethane $(CHFBr_2)$	VII	1
62	HBFC-22B1	Bromodifluoromethane (CHF_2Br)	VII	0.74
63		Bromofluoromethane (CH_2FBr)	VII	0.73
64		Tetrabromofluoroethane (C_2HFBr_4)	VII	0.8
65		Tribromodifluoroethane $(C_2HF_2Br_3)$	VII	1.8
66	HBFC-123B2 HBFC-123aB2	Dibromotrifluoroethane $(C_2HF_3Br_2)$	VII	1.6
67	HBFC-124B1	Bromotetrafluoroethane (C_2HF_4Br)	VII	1.2
68		Tribromofluoroethane $(C_2H_2FBr_3)$	VII	1.1
69		Dibromodifluoroethane $(C_2H_2F_2Br_2)$	VII	1.5
70		Bromotrifluoroethane	VII	1.6

		$(C_2H_2F_3Br)$		
71		Dibromofluoroethane $(C_2H_3FBr_2)$	VII	1.7
72	HBFC-124B1	Bromodifluoroethane $(C_2H_3F_2Br)$	VII	1.1
73	HBFC-124B1	Bromofluoroethane (C_2H_4FBr)	VII	0.1
74		Haxabromofluoropropane (C_3HFB_6)	VII	1.5
75		Pentabromodifluoropropane $(C_3HF_2Br_5)$	VII	1.9
76		Tetrabromofluoropropane $(C_3HF_3Br_4)$	VII	1.8
77		Tribromotetrafluoropropane $(C_3HF_4Br_3)$	VII	2.2
78		Dibromopentafluoropropane $(C_3HF_5Br_2)$	VII	2
79		Bromohaxafluoropropane (C_3HF_6Br)	VII	3.3
80		Pentabromofluoropropane $(C_3H_2FBr_5)$	VII	1.9
81		Tetrabromodifluoropropane $(C_3H_2F_2Br_4)$	VII	2.1
82		Tribromotrifluoropropane $(C_3H_2F_3Br_3)$	VII	5.6
83		Dibromotetrafluoropropane $(C_3H_2F_4Br_2)$	VII	7.5
84		Bromopentafluoropropane $(C_3H_2F_5Br)$	VII	1.4
85		Tetrabromofluoropropane	VII	1.9

		($C_3H_3FBr_4$)		
86		Tribromodifluoropropane ($C_3H_3F_2Br_3$)	VII	3.1
87		Dibromotriflvoropropane ($C_3H_3F_3Br_2$)	VII	2.5
88		Bromotetrafluoropropane ($C_3H_3F_4Br$)	VII	4.4
89		Tribromofluoropropane ($C_3H_4FBr_3$)	VII	0.3
90		Dibromodifluoropropane ($C_3H_4F_2Br_2$)	VII	1
91		Bromotrifluoropropane ($C_3H_4F_3Br$)	VII	0.8
92		Dibromofluoropropane ($C_3H_5FBr_2$)	VII	0.4
93		Bromodifluoropropane ($C_3H_5F_2Br$)	VII	0.8
94		Bromofluoropropane (C_3H_6FBr)	VII	0.7
95	Methyl bromide	(CH_3Br)	VIII	0.6

Candidate List (Inclusions)

ID No Substance Name EC Number CAS Number Submitted By Date of Inclusion Reason for Inclusion Scope Decision Number

171 Distillates (coal tar), pitch, pyrene fraction 295-313-4 91995-52-7 ECHA Pending Pending PBT Pending

170 Residues (coal tar), pitch distn. 295-507-9 92061-94-4 ECHA Pending Pending PBT Pending

169 Benzo[def]chrysene (Benzo[a]pyrene) [Benzo[a]pyrene and all substances that contain benzo[a]pyrene at a concentration equal to or greater than 0.01 % by weight.] 200-028-5 50-32-8 Germany Pending Pending CMR, PBT Pending

168 Distillates (coal tar), heavy oils 292-607-4 90640-86-1 ECHA Pending Pending PBT Pending

167 Distillates (coal tar), heavy oils, pyrene fraction 295-304-5 91995-42-5 ECHA Pending Pending PBT Pending

166 Further Arsenic compounds - - Norway Pending Pending CMR Pending

165 2-ethylhexyl 10-ethyl-4,4-dioctyl-7-oxo-8-oxa-3,5-dithia-4-stannatetradecanoate (DOTE) 239-622-4 15571-58-1 Austria 17/12/2014 Pending CMR Pending

164 Reaction mass of 2-ethylhexyl 10-ethyl-4,4-dioctyl-7-oxo-8-oxa-3,5-dithia-4-stannatetradecanoate and 2-ethylhexyl 10-ethyl-4-[[2-[(2-ethylhexyl)oxy]-2-oxoethyl]thio]-4-octyl-7-oxo-8-oxa-3,5-dithia-4-stannatetradecanoate (reaction mass of DOTE and MOTE) Austria 17/12/2014 Pending CMR Pending

163 Bis(2-ethylhexyl) phthalate 204-211-0 117-81-7 Denmark 04/08/2014 Pending ED Pending

162 2-benzotriazol-2-yl-4,6-di-tert-butylphenol (UV-320) 223-346-6 68515-50-4 Germany 17/12/2014 Pending PBT Pending

161 Dibutyl phthalate 201-557-4 84-74-2 Denmark 04/08/2014 Pending ED Pending

160 2-(2H-benzotriazol-2-yl)-4,6-ditertpentylphenol (UV-328) 247-384-8 68515-50-4 Germany 17/12/2014 Pending PBT Pending

159 Cadmium sulphate 232-331-6 68515-50-4 Sweden 17/12/2014 Pending CMR Pending

158 Cadmium fluoride 232-222-0 68515-50-4 Sweden 17/12/2014 Pending CMR Pending

157 Diisobutyl phthalate 201-553-2 84-69-5 Denmark 04/08/2014 Pending ED Pending

156 Benzyl butyl phthalate 201-622-7 85-68-7 Denmark 28/10/2008 Toxic for reproduction (Article 57 c) ED EU/2017/4462

155 1,2-Benzenedicarboxylic acid, dihexyl ester, branched and linear 271-093-5 68515-50-4 Sweden 16/06/2014 Toxic for reproduction (Article 57 c) CMR ED/49/2014

154 Sodium perborate; perboric acid, sodium salt239-172-9; 234-390-0 - Denmark 16/06/2014 Toxic for reproduction (Article 57 c) CMR ED/49/2014

153 Sodium peroxometaborate 231-556-4 04/04/7632 Denmark 16/06/2014 Toxic for reproduction (Article 57 c) CMR ED/49/2014

152 Cadmium chloride 233-296-7 10108-64-2 Sweden 16/06/2014 Carcinogenic (Article 57a); CMR, Other ED/49/2014

Mutagenic (Article 57b);

Toxic for reproduction (Article 57c);

Equivalent level of concern having probable serious effects to human health (Article 57 f)

151 Cadmium sulphide 215-147-8 1306-23-6 Sweden 16/12/2013 Carcinogenic (Article 57a); CMR, Other ED/121/2013

Equivalent level of concern having probable serious effects to human health (Article 57 f)

150 Trixylyl phosphate 246-677-8 25155-23-1 Austria16/12/2013 Toxic for reproduction (Article 57 c) CMR ED/121/2013

149 Disodium 4-amino-3-[[4'-[(2,4-diaminophenyl)azo][1,1'-biphenyl]-4-yl]azo] -5-hydroxy-6-(phenylazo)naphthalene-2,7-disulphonate (C.I. Direct Black 38) 217-710-3 1937-37-7 Netherlands 16/12/2013 Carcinogenic (Article 57a) CMR ED/121/2013

148 Imidazolidine-2-thione; (2-imidazoline-2-thiol) 202-506-9 96-45-7 Sweden 16/12/2013 Toxic for reproduction (Article 57 c) CMR ED/121/2013

147 Lead di(acetate) 206-104-4 301-04-2 Netherlands 16/12/2013 Toxic for reproduction (Article 57 c) CMR ED/121/2013

146 Dihexyl phthalate 201-559-5 84-75-3 Germany 16/12/2013 Toxic for reproduction (Article 57 c) CMR ED/121/2013

145 Disodium 3,3'-[[1,1'-biphenyl]-4,4'-diylbis(azo)]bis(4-aminonaphthalene-1-sulphonate) (C.I. Direct Red 28) 209-358-4 573-58-0 Netherlands 16/12/2013 Carcinogenic (Article 57a) CMR ED/121/2013

144 Cadmium 231-152-8 7440-43-9 Sweden 20/06/2013 Carcinogenic (Article 57a); Equivalent level of concern having probable serious effects to human health (Article 57 f) CMR, Other ED/69/2013

143 4-Nonylphenol, branched and linear, ethoxylated [substances with a linear and/or branched alkyl chain with a carbon number of 9 covalently bound in position 4 to phenol, ethoxylated covering UVCB- and well-defined substances, polymers and homologues, which include any of the individual isomers and/or combinations thereof] - - Germany 20/06/2013 Equivalent level of concern having probable serious effects to the environment (Article 57 f) ED ED/69/2013

142 Ammonium pentadecafluorooctanoate (APFO) 223-320-4 3825-26-1 Germany 20/06/2013 Toxic for reproduction (Article 57 c); CMR, PBT ED/69/2013

PBT (Article 57 d)

141 Pentadecafluorooctanoic acid (PFOA) 206-397-9 335-67-1 Germany 20/06/2013 Toxic for reproduction (Article 57 c); CMR, PBT ED/69/2013

PBT (Article 57 d)

140 Dipentyl phthalate (DPP) 205-017-9 131-18-0 Poland 20/06/2013 Toxic for reproduction (Article 57 c) CMR ED/69/2013

139 Cadmium oxide 215-146-2 1306-19-0 Sweden 20/06/2013 Carcinogenic (Article 57a); Equivalent level of concern having probable serious effects to human health (Article 57 f) CMR, Other ED/69/2013

138 Hexahydromethylphthalic anhydride [1], Hexahydro-4-methylphthalic anhydride [2], Hexahydro-1-methylphthalic anhydride [3], Hexahydro-3-methylphthalic anhydride [4] [The individual isomers [2], [3] and [4] (including their cis- and trans- stereo isomeric forms) and all possible combinations of the isomers [1] are covered by this entry] 247-094-1, 243-072-0, 256-356-4, 260-566-1 25550-51-0, 19438-60-9, 48122-14-1, 57110-29-9 Netherlands 19/12/2012 Equivalent level of concern having probable serious effects to human health (Article 57 f) EQC ED/169/2012

137 6-methoxy-m-toluidine (p-cresidine) 204-419-1 120-71-8 ECHA 19/12/2012 Carcinogenic (Article 57a) CMR ED/169/2012

136 Cyclohexane-1,2-dicarboxylic anhydride [1], cis-cyclohexane-1,2-dicarboxylic anhydride [2], trans-cyclohexane-1,2-dicarboxylic anhydride [3] [The individual cis- [2] and trans- [3] isomer substances and all possible combinations of the cis- and trans-isomers [1] are covered by this entry] 201-604-9, 236-086-3, 238-009-9 85-42-7, 13149-00-3,

14166-21-3 Netherlands 19/12/2012 Equivalent level of concern having probable serious effects to human health (Article 57 f)EQC ED/169/2012

135 Pyrochlore, antimony lead yellow 232-382-1 8012-00-8 ECHA 19/12/2012 Toxic for reproduction (Article 57 c) CMR ED/169/2012

134 Henicosafluoroundecanoic acid 218-165-4 2058-94-8 Germany 19/12/2012 vPvB (Article 57 e) PBT ED/169/2012

133 4-Aminoazobenzene 200-453-6 60-09-3 ECHA 19/12/2012 Carcinogenic (Article 57a) CMR ED/169/2012

132 Silicic acid, lead salt 234-363-3 11120-22-2 ECHA 19/12/2012 Toxic for reproduction (Article 57 c) CMR ED/169/2012

131 Lead titanium zirconium oxide 235-727-4 12626-81-2 ECHA 19/12/2012 Toxic for reproduction (Article 57 c) CMR ED/169/2012

130 Lead monoxide (lead oxide) 215-267-0 1317-36-8 ECHA 19/12/2012 Toxic for reproduction (Article 57 c) CMR ED/169/2012

129 o-Toluidine 202-429-0 95-53-4 ECHA 19/12/2012 Carcinogenic (Article 57a) CMR ED/169/2012

128 3-ethyl-2-methyl-2-(3-methylbutyl)-1,3-oxazolidine 421-150-7 143860-04-2 ECHA 19/12/2012 Toxic for reproduction (Article 57 c) CMR ED/169/2012

127 Dibutyltin dichloride (DBTC)211-670-0 683-18-1 Sweden 19/12/2012 Toxic for reproduction (Article 57 c) CMR ED/169/2012

126 Lead bis(tetrafluoroborate) 237-486-0 13814-96-5 ECHA 19/12/2012 Toxic for reproduction (Article 57 c) CMR ED/169/2012

125 Lead dinitrate 233-245-9 10099-74-8 ECHA 19/12/2012 Toxic for reproduction (Article 57 c) CMR ED/169/2012

124 Silicic acid (H2Si2O5), barium salt (1:1), lead-doped 272-271-5 68784-75-8 ECHA 19/12/2012 Toxic for reproduction (Article 57 c) CMR ED/169/2012

[with lead (Pb) content above the applicable generic concentration limit for 'toxicity for reproduction' Repr. 1A (CLP) or category 1 (DSD); the substance is a member of the group entry of lead compounds, with index number 082-001-00-6 in Regulation (EC) No 1272/2008]

123 Trilead bis(carbonate)dihydroxide 215-290-6 1319-46-6 ECHA 19/12/2012 Toxic for reproduction (Article 57 c) CMR ED/169/2012

122 4,4'-methylenedi-o-toluidine 212-658-8 838-88-0 ECHA 19/12/2012 Carcinogenic (Article 57a) CMR ED/169/2012

121 Diethyl sulphate 200-589-6 64-67-5 ECHA 19/12/2012 Carcinogenic (Article 57a); Mutagenic (Article 57b)CMR ED/169/2012

120 Dimethyl sulphate 201-058-1 77-78-1 ECHA 19/12/2012 Carcinogenic (Article 57a) CMR ED/169/2012

119 N,N-dimethylformamide 200-679-5 68-12-2 Sweden 19/12/2012 Toxic for reproduction (Article 57 c) CMR ED/169/2012

118 4-(1,1,3,3-tetramethylbutyl)phenol, ethoxylated [covering well-defined substances and UVCB substances, polymers and homologues] - - Unlisted 19/12/2012 Equivalent level of concern having probable serious effects to the environment (Article 57 f) ED ED/169/2012

117 4-Nonylphenol, branched and linear [substances with a linear and/or branched alkyl chain with a carbon number of 9 covalently bound in position 4 to phenol, covering also UVCB- and well-defined substances which include any of the individual isomers or a combination thereof] - - Germany 19/12/2012 Equivalent level of concern having probable serious effects to the environment (Article 57 f) ED ED/169/2012

116 Furan 203-727-3 110-00-9 ECHA 19/12/2012 Carcinogenic (Article 57a) CMR ED/169/2012

115 Lead oxide sulfate 234-853-7 12036-76-9 ECHA 19/12/2012 Toxic for reproduction (Article 57 c) CMR ED/169/2012

114 Lead titanium trioxide 235-038-9 12060-00-3 ECHA 19/12/2012 Toxic for reproduction (Article 57 c) CMR ED/169/2012

113 Bis(pentabromophenyl) ether (decabromodiphenyl ether; DecaBDE) 214-604-9 1163-19-5 UK 19/12/2012 PBT (Article 57 d); vPvB (Article 57 e) PBT ED/169/2012

112 Dinoseb (6-sec-butyl-2,4-dinitrophenol) 201-861-7 88-85-7 ECHA 19/12/2012 Toxic for reproduction (Article 57 c) CMR ED/169/2012

111 1,2-Diethoxyethane 211-076-1 629-14-1 Slovakia 19/12/2012 Toxic for reproduction (Article 57 c) CMR ED/169/2012

110 N-methylacetamide 201-182-6 79-16-3 ECHA 19/12/2012 Toxic for reproduction (Article 57 c) CMR ED/169/2012

109 Tetralead trioxide sulphate 235-380-9 12202-17-4 ECHA 19/12/2012 Toxic for reproduction (Article 57 c) CMR ED/169/2012

108 Acetic acid, lead salt, basic 257-175-3 51404-69-4 ECHA 19/12/2012 Toxic for reproduction (Article 57 c) CMR ED/169/2012

107 [Phthalato(2-)]dioxotrilead 273-688-5 69011-06-9 ECHA 19/12/2012 Toxic for reproduction (Article 57 c) CMR ED/169/2012

106 Tetraethyllead 201-075-4 78-00-2 ECHA 19/12/2012 Toxic for reproduction (Article 57 c) CMR ED/169/2012

105 N-pentyl-isopentylphthalate - 776297-69-9 Germany 19/12/2012 Toxic for reproduction (Article 57 c) CMR ED/169/2012

104 Pentalead tetraoxide sulphate 235-067-7 12065-90-6 ECHA 19/12/2012 Toxic for reproduction (Article 57 c) CMR ED/169/2012

103 Heptacosafluorotetradecanoic acid 206-803-4 376-06-7 Germany 19/12/2012 vPvB (Article 57 e) PBT ED/169/2012

102 Tricosafluorododecanoic acid 206-203-2 307-55-1 Germany 19/12/2012 vPvB (Article 57 e) PBT ED/169/2012

101 1-bromopropane (n-propyl bromide) 203-445-0 106-94-5 ECHA 19/12/2012 Toxic for reproduction (Article 57 c) CMR ED/169/2012

100 Dioxobis(stearato)trilead 235-702-8 12578-12-0 ECHA 19/12/2012 Toxic for reproduction (Article 57 c) CMR ED/169/2012

99 Pentacosafluorotridecanoic acid 276-745-2 72629-94-8 Germany 19/12/2012 vPvB (Article 57 e) PBT ED/169/2012

98 Methoxyacetic acid 210-894-6 625-45-6 Sweden 19/12/2012 Toxic for reproduction (Article 57 c) CMR ED/169/2012

97 Methyloxirane (Propylene oxide) 200-879-2 75-56-9 ECHA 19/12/2012 Carcinogenic (Article 57a); Mutagenic (Article 57b)CMR ED/169/2012

96 Trilead dioxide phosphonate 235-252-2 12141-20-7 ECHA 19/12/2012 Toxic for reproduction (Article 57 c) CMR ED/169/2012

95 o-aminoazotoluene 202-591-2 97-56-3 ECHA 19/12/2012 Carcinogenic (Article 57a) CMR ED/169/2012

94 4-methyl-m-phenylenediamine (toluene-2,4-diamine) 202-453-1 95-80-7 ECHA 19/12/2012 Carcinogenic (Article 57a) CMR ED/169/2012

93 Diisopentylphthalate 210-088-4 605-50-5 Austria 19/12/2012 Toxic for reproduction (Article 57 c) CMR ED/169/2012

92 1,2-Benzenedicarboxylic acid, dipentylester, branched and linear 284-032-2 84777-06-0 Germany 19/12/2012 Toxic for reproduction (Article 57 c) CMR ED/169/2012

91 Biphenyl-4-ylamine 202-177-1 92-67-1 ECHA 19/12/2012 Carcinogenic (Article 57a) CMR ED/169/2012

90 Fatty acids, C16-18, lead salts 292-966-7 91031-62-8 ECHA 19/12/2012 Toxic for reproduction (Article 57 c) CMR ED/169/2012

89 Orange lead (lead tetroxide) 215-235-6 1314-41-6 ECHA 19/12/2012 Toxic for reproduction (Article 57 c) CMR ED/169/2012

88 4,4'-oxydianiline and its salts 202-977-0 101-80-4 ECHA 19/12/2012 Carcinogenic (Article 57a); Mutagenic (Article 57b) CMR ED/169/2012

87 Diazene-1,2-dicarboxamide (C,C'-azodi(formamide)) 204-650-8 123-77-3 Austria 19/12/2012 Equivalent level of concern having probable serious effects to human health (Article 57 f) EQC ED/169/2012

86 Sulfurous acid, lead salt, dibasic 263-467-1 62229-08-7 ECHA 19/12/2012 Toxic for reproduction (Article 57 c) CMR ED/169/2012

85 Lead cyanamidate 244-073-9 20837-86-9 ECHA 19/12/2012 Toxic for reproduction (Article 57 c) CMR ED/169/2012

84 α,α-Bis[4-(dimethylamino)phenyl]-4 (phenylamino)naphthalene-1-methanol (C.I. Solvent Blue 4) [with ≥ 0.1% of Michler's ketone (EC No. 202-027-5) or Michler's base (EC No. 202-959-2)] 229-851-8 6786-83-0 ECHA 18/06/2012 Carcinogenic (Article 57a) CMR ED/87/2012

83 [4-[4,4'-bis(dimethylamino) benzhydrylidene]cyclohexa-2,5-dien-1-ylidene]dimethylammonium chloride (C.I. Basic Violet 3) [with ≥ 0.1% of Michler's ketone (EC No. 202-027-5) or Michler's base (EC No. 202-959-2)] 208-953-6 548-62-9 ECHA 18/06/2012 Carcinogenic (Article 57a) CMR ED/87/2012

82 N,N,N',N'-tetramethyl-4,4'-methylenedianiline (Michler's base) 202-959-2 101-61-1 ECHA 18/06/2012 Carcinogenic (Article 57a) CMR ED/87/2012

81 1,3,5-tris[(2S and 2R)-2,3-epoxypropyl]-1,3,5-triazine-2,4,6-(1H,3H,5H)-trione (β-TGIC) 423-400-0 59653-74-6 Netherlands 18/06/2012 Mutagenic (Article 57b) CMR ED/87/2012

80 Diboron trioxide 215-125-8 1303-86-2 Germany 18/06/2012 Toxic for reproduction (Article 57 c) CMR ED/87/2012

79 1,2-bis(2-methoxyethoxy)ethane (TEGDME; triglyme) 203-977-3 112-49-2 Belgium 18/06/2012 Toxic for reproduction (Article 57 c) CMR ED/87/2012

78 Formamide 200-842-0 75-12-7 Germany 18/06/2012 Toxic for reproduction (Article 57 c) CMR ED/87/2012

77 4,4'-bis(dimethylamino)-4''-(methylamino)trityl alcohol [with ≥ 0.1% of Michler's ketone (EC No. 202-027-5) or Michler's base (EC No. 202-959-2)] 209-218-2 561-41-1 ECHA 18/06/2012 Carcinogenic (Article 57a) CMR ED/87/2012

76 Lead(II) bis(methanesulfonate) 401-750-5 17570-76-2 Netherlands 18/06/2012 Toxic for reproduction (Article 57 c) CMR ED/87/2012

75 1,2-dimethoxyethane; ethylene glycol dimethyl ether (EGDME) 203-794-9 110-71-4 Belgium 18/06/2012 Toxic for reproduction (Article 57 c) CMR ED/87/2012

74 [4-[[4-anilino-1-naphthyl][4-(dimethylamino)phenyl]methylene]cyclohexa-2,5-dien-1-ylidene] dimethylammonium chloride (C.I. Basic Blue 26) [with ≥ 0.1% of Michler's ketone (EC No. 202-027-5) or Michler's base (EC No. 202-959-2)] 219-943-6 2580-56-5 ECHA 18/06/2012 Carcinogenic (Article 57a) CMR ED/87/2012

73 1,3,5-Tris(oxiran-2-ylmethyl)-1,3,5-triazinane-2,4,6-trione (TGIC) 219-514-3 2451-62-9 Netherlands 18/06/2012 Mutagenic (Article 57b) CMR ED/87/2012

72 4,4'-bis(dimethylamino)benzophenone (Michler's ketone) 202-027-5 90-94-8 ECHA 18/06/2012 Carcinogenic (Article 57a) CMR ED/87/2012

71 Phenolphthalein 201-004-7 77-09-8 ECHA 19/12/2011 Carcinogenic (article 57 a) CMR ED/77/2011

70 N,N-dimethylacetamide 204-826-4 127-19-5 ECHA 19/12/2011 Toxic for reproduction (article 57 c) CMR ED/77/2011

69 4-(1,1,3,3-tetramethylbutyl)phenol 205-426-2 140-66-9 Germany 19/12/2011 Equivalent level of concern having probable serious effects to the environment (article 57 f) EQC ED/77/2011

68 Lead diazide, Lead azide 236-542-1 13424-46-9 ECHA 19/12/2011 Toxic for reproduction (article 57 c), CMR ED/77/2011

67 Lead dipicrate 229-335-2 6477-64-1 ECHA 19/12/2011 Toxic for reproduction (article 57 c) CMR ED/77/2011

66 1,2-dichloroethane 203-458-1 107-06-2 Slovakia 19/12/2011 Carcinogenic (article 57 a) CMR ED/77/2011

65 Aluminosilicate Refractory Ceramic Fibres are fibres covered by index number 650-017-00-8 in Annex VI, part 3, table 3.1 of Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labelling and packaging of substances and mixtures, and fulfil the three following conditions: a) oxides of aluminium and silicon are the main components present (in the fibres) within variable concentration ranges b) fibres have a length weighted geometric mean diameter less two standard geometric errors of 6 or less micrometres (μm) c) alkaline oxide and alkali earth oxide ($Na_2O+K_2O+CaO+MgO+BaO$) content less or equal to 18% by weight - - Germany 19/12/2011 Carcinogenic (article 57 a) CMR ED/77/2011

ED/95/2012

64 Calcium arsenate 231-904-5 7778-44-1 Norway 19/12/2011 Carcinogenic (article 57 a) CMR ED/77/2011

63 Dichromium tris(chromate) 246-356-2 24613-89-6 France 19/12/2011 Carcinogenic (article 57 a) CMR ED/77/2011

62 2-Methoxyaniline; o-Anisidine 201-963-1 90-04-0 Germany 19/12/2011 Carcinogenic (article 57 a) CMR ED/77/2011

61 Pentazinc chromate octahydroxide 256-418-0 49663-84-5 France 19/12/2011 Carcinogenic (article 57 a) CMR ED/77/2011

60 Arsenic acid 231-901-9 7778-39-4 Norway 19/12/2011 Carcinogenic (article 57 a) CMR ED/77/2011

59 Potassium hydroxyoctaoxodizincatedichromate 234-329-8 11103-86-9 France 19/12/2011 Carcinogenic (article 57 a) CMR ED/77/2011

58 Formaldehyde, oligomeric reaction products with aniline 500-036-1 25214-70-4 Germany 19/12/2011 Carcinogenic (article 57 a) CMR ED/77/2011

57 Lead styphnate 239-290-0 15245-44-0 ECHA 19/12/2011 Toxic for reproduction (article 57 c) CMR ED/77/2011

56 Bis(2-methoxyethyl) phthalate 204-212-6 117-82-8 Germany 19/12/2011 Toxic for reproduction (article 57 c) CMR ED/77/2011

55 Trilead diarsenate 222-979-5 3687-31-8 Norway 19/12/2011 Carcinogenic and toxic for reproduction (articles 57 a and 57 c) CMR ED/77/2011

54 Bis(2-methoxyethyl) ether 203-924-4 111-96-6 Austria 19/12/2011 Toxic for reproduction (article 57 c) CMR ED/77/2011

53 2,2'-dichloro-4,4'-methylenedianiline 202-918-9 101-14-4 ECHA 19/12/2011 Carcinogenic (article 57 a) CMR ED/77/2011

52 Zirconia Aluminosilicate Refractory Ceramic Fibres are fibres covered by index number 650-017-00-8 in Annex VI, part 3, table 3.1 of Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labelling and packaging of substances and mixtures, and fulfil the three following conditions: a) oxides of aluminium, silicon and zirconium are the main components present (in the fibres) within variable concentration ranges b) fibres have a length weighted geometric mean diameter less two standard geometric errors of 6 or less micrometres (µm). c) alkaline oxide and alkali earth oxide (Na2O+K2O+CaO+MgO+BaO) content less or equal to 18% by weight - - Germany 19/12/2011 Carcinogenic (article 57 a) CMR ED/77/2011

ED/95/2012

51 Cobalt dichloride 231-589-4 7646-79-9 France 20/06/2011 Carcinogenic and toxic for reproduction (articles 57 a and 57 c) CMR ED/31/2011 / ED/67/2008

50	1,2-Benzenedicarboxylic acid, di-C6-8-branched alkyl esters, C7-rich	276-158-1	71888-89-6	ECHA 20/06/2011	Toxic for reproduction (article 57c)	CMR	ED/31/2011

49	Strontium chromate	232-142-6	02/06/7789	France 20/06/2011	Carcinogenic (article 57a)	CMR	ED/31/2011

48	1,2-Benzenedicarboxylic acid, di-C7-11-branched and linear alkyl esters	271-084-6	68515-42-4	Denmark	20/06/2011	Toxic for reproduction (article 57c)	CMR	ED/31/2011

47	1-Methyl-2-pyrrolidone	212-828-1	872-50-4	ECHA 20/06/2011	Toxic for reproduction (article 57c)	CMR	ED/31/2011

46	1,2,3-Trichloropropane	202-486-1	96-18-4	ECHA 20/06/2011	Carcinogenic and toxic for reproduction (articles 57 a and 57 c)	CMR	ED/31/2011

45	2-Ethoxyethyl acetate 203-839-2	111-15-9	Belgium	20/06/2011	Toxic for reproduction (article 57c)	CMR	ED/31/2011

44	Hydrazine	206-114-9	302-01-2, 7803-57-8	ECHA 20/06/2011	Carcinogenic (article 57a)	CMR	ED/31/2011

43	Cobalt(II) diacetate	200-755-8	71-48-7	Netherlands	15/12/2010	Carcinogenic and toxic for reproduction (articles 57 a and 57 c)	CMR	ED/95/2010

42	2-Ethoxyethanol	203-804-1	110-80-5	Austria 15/12/2010	Toxic for reproduction (article 57c)	CMR	ED/95/2010

41	Cobalt(II) sulphate	233-334-2	10124-43-3	Netherlands	15/12/2010	Carcinogenic and toxic for reproduction (articles 57 a and 57 c)	CMR	ED/95/2010

40	Acids generated from chromium trioxide and their oligomers. Names of the acids and their oligomers: Chromic acid, Dichromic acid, Oligomers of chromic acid and dichromic acid.	231-801-5, 236-881-5 7738-94-5, 13530-68-2	Germany	15/12/2010	Carcinogenic (article 57a)	CMR	ED/95/2010

39	2-Methoxyethanol	203-713-7	109-86-4	Austria 15/12/2010	Toxic for reproduction (article 57c)	CMR	ED/95/2010

38	Chromium trioxide	215-607-8	1333-82-0	Germany	15/12/2010	Carcinogenic and mutagenic (articles 57 a and 57 b)	CMR	ED/95/2010

37	Cobalt(II) carbonate	208-169-4	513-79-1	Netherlands	15/12/2010	Carcinogenic and toxic for reproduction (articles 57 a and 57 c)	CMR	ED/95/2010

36 Cobalt(II) dinitrate 233-402-1 10141-05-6 Netherlands 15/12/2010 Carcinogenic and toxic for reproduction (articles 57 a and 57 c) CMR ED/95/2010

35 Trichloroethylene 201-167-4 79-01-6 France 18/06/2010 Carcinogenic (article 57 a) CMR ED/30/2010

34 Potassium dichromate 231-906-6 7778-50-9 France 18/06/2010 Carcinogenic, mutagenic and toxic for reproduction (articles 57 a, 57 b and 57 c) CMR ED/30/2010

33 Tetraboron disodium heptaoxide, hydrate 235-541-3 12267-73-1 Denmark 18/06/2010 Toxic for reproduction (article 57 c) CMR ED/30/2010

32 Boric acid 233-139-2, 234-343-4 10043-35-3, 11113-50-1 Germany 18/06/2010 Toxic for reproduction (article 57 c) CMR ED/30/2010

31 Ammonium dichromate 232-143-1 05/09/7789 France 18/06/2010 Carcinogenic, mutagenic and toxic for reproduction (articles 57 a, 57 b and 57 c) CMR ED/30/2010

30 Sodium chromate 231-889-5 03/11/7775 France 18/06/2010 Carcinogenic, mutagenic and toxic for reproduction (articles 57 a, 57 b and 57 c) CMR ED/30/2010

29 Disodium tetraborate, anhydrous 215-540-4 1303-96-4, 1330-43-4, 12179-04-3 Denmark 18/06/2010 Toxic for reproduction (article 57 c) CMR ED/30/2010

28 Potassium chromate 232-140-5 7789-00-6 France 18/06/2010 Carcinogenic and mutagenic (articles 57 a and 57 b). CMR ED/30/2010

27 Acrylamide 201-173-7 79-06-1 Netherlands 30/03/2010 Carcinogenic and mutagenic (articles 57 a and 57 b) CMR ED/68/2009

26 Lead sulfochromate yellow (C.I. Pigment Yellow 34) 215-693-7 1344-37-2 France 13/01/2010 Carcinogenic and toxic for reproduction (articles 57 a and 57 c)) CMR ED/68/2009

25 Lead chromate molybdate sulphate red (C.I. Pigment Red 104) 235-759-9 12656-85-8 France 13/01/2010 Carcinogenic and toxic for reproduction (articles 57 a and 57 c) CMR ED/68/2009

24 2,4-Dinitrotoluene 204-450-0 121-14-2 Spain 13/01/2010 Carcinogenic (article 57a) CMR ED/68/2009

23 Anthracene oil 292-602-7 90640-80-5 Germany 13/01/2010 Carcinogenic1, PBT and vPvB (articles 57a, 57d and 57e) PBT ED/68/2009

22 Anthracene oil, anthracene paste, anthracene fraction 295-275-9 91995-15-2 Germany 13/01/2010 Carcinogenic2, mutagenic3, PBT and vPvB (articles 57a, 57b, 57d and 57e) PBT ED/68/2009

21 Anthracene oil, anthracene-low 292-604-8 90640-82-7 Germany 13/01/2010 Carcinogenic2, mutagenic3, PBT and vPvB (articles 57a, 57b, 57d and 57e) PBT ED/68/2009

20 Diisobutyl phthalate 201-553-2 84-69-5 Germany 13/01/2010 Toxic for reproduction (article 57c) CMR ED/68/2009

19 Tris(2-chloroethyl)phosphate 204-118-5 115-96-8 Austria 13/01/2010 Toxic for reproduction (article 57c) CMR ED/68/2009

18 Lead chromate 231-846-0 7758-97-6 France 13/01/2010 Carcinogenic and toxic for reproduction (articles 57 a and 57 c) CMR ED/68/2009

17 Anthracene oil, anthracene paste 292-603-2 90640-81-6 Germany 13/01/2010 Carcinogenic2, mutagenic3, PBT and vPvB (articles 57a, 57b, 57d and 57e) PBT ED/68/2009

16 Pitch, coal tar, high temp. 266-028-2 65996-93-2 ECHA 13/01/2010 Carcinogenic, PBT and vPvB (articles 57a, 57d and 57e) PBT ED/68/2009

15 Anthracene oil, anthracene paste,distn. lights 295-278-5 91995-17-4 Germany 13/01/2010 Carcinogenic2, mutagenic3, PBT and vPvB (articles 57a, 57b, 57d and 57e) PBT ED/68/2009

14 Lead hydrogen arsenate 232-064-2 7784-40-9 Norway 28/10/2008 Carcinogenic and toxic for reproduction (articles 57 a and 57 c) CMR ED/67/2008

13 Benzyl butyl phthalate (BBP) 201-622-7 85-68-7 Austria 28/10/2008 Toxic for reproduction (article 57c) CMR ED/67/2008

12 Bis (2-ethylhexyl)phthalate (DEHP) 204-211-0 117-81-7 Denmark 28/10/2008 Toxic for reproduction (article 57c) ED ED/67/2008

11 Bis(tributyltin)oxide (TBTO) 200-268-0 56-35-9 Norway 28/10/2008 PBT (article 57d) CMR ED/67/2008

10 5-tert-butyl-2,4,6-trinitro-m-xylene (musk xylene) 201-329-4 81-15-2 Netherlands 28/10/2008 vPvB (article 57e) vPvB ED/67/2008

9 Diarsenic trioxide 215-481-4 1327-53-3 France 28/10/2008 Carcinogenic (article 57a) CMR ED/67/2008

8 Triethyl arsenate 427-700-2 15606-95-8 Norway 28/10/2008 Carcinogenic (article 57a) Not Scoped ED/67/2008

7 Diarsenic pentaoxide 215-116-9 1303-28-2 France 28/10/2008 Carcinogenic (article 57a) CMR ED/67/2008

6 Sodium dichromate 234-190-3 7789-12-0, 10588-01-9 France 28/10/2008 Carcinogenic, mutagenic and toxic for reproduction (articles 57a, 57b and 57c) CMR ED/67/2008

5 Dibutyl phthalate (DBP) 201-557-4 84-74-2 Denmark 28/10/2008 Toxic for reproduction (article 57c) ED ED/67/2008

4 4,4'- Diaminodiphenylmethane (MDA) 202-974-4 101-77-9 Germany 28/10/2008 Carcinogenic (article 57a) CMR ED/67/2008

3 Alkanes, C10-13, chloro (Short Chain Chlorinated Paraffins) 287-476-5 85535-84-8 UK 28/10/2008 PBT and vPvB (articles 57 d and 57 e) PBT ED/67/2008

2 Anthracene 204-371-1 120-12-7 Germany 28/10/2008 PBT (article 57d) PBT ED/67/2008

1 Hexabromocyclododecane (HBCDD) and all major diastereoisomers identified: Alpha-hexabromocyclododecane Beta-hexabromocyclododecane Gamma-hexabromocyclododecane 247-148-4 and 221-695-9 25637-99-4, 3194-55-6 (134237-50-6) (134237-51-7) (134237-52-8)Sweden 28/10/2008 PBT (article 57d) PBT ED/67/2008

Set of Circular Economy (CE) principles from different sources.
Source Principles Description

BS 8001:2017, The British Standards Institution
Systems thinking
Adoption of a holistic approach to understanding the interaction within the broader systems.
Innovation
Innovation to create value by better managing resources through the design of processes, products/services, and business models.
Stewardship
Management of direct and indirect impacts of decisions and activities within the broader system of a company.
Collaboration
Internal and external collaboration through formal and informal arrangements to create mutual value.
Value optimization
Products, components, and materials are always kept at their highest value and utility.
Transparency
Willingness to communicate circular and sustainability practices in a transparent, accurate, timely, honest, and complete manner.

Circle Economy
Prioritize regenerative resources
Renewable, reusable, non-toxic resources are efficiently utilized as materials and energy.
Preserve and extend what is already made products are maintained, repaired, and upgraded to maximize lifetime and give them a second life when applicable.
Use waste as a resource, waste streams are used as a source of secondary resources and recovered for reuse and recycling.
Rethink the business model business models that blur the distinction between products and services, creating higher value and aligning incentives.
Design for the future Think in systems during the design process, use the right materials, design
for an appropriate lifetime and extended future use.
Incorporate digital technology, Tracking and optimization of resource use stronger connections between supply chain actors through technology.
Collaborate to create joint value, Internal and external collaborations to increase transparency and create joint value.

Ellen Macarthur Foundation
Design out waste and pollution
A new mindset that sees waste as a design flaw and uses new materials and technologies.
Keep products and materials in use
Products and materials are kept in the economy through reuse, repair, and remanufacture. Materials are collected to be reused.
Regenerate natural systems
Valuable nutrients are returned to the environment to regenerate natural ecosystems.

Suárez-Eiroa et al.
Adjusting inputs to the system to regeneration rates
Input of non-renewable resources is minimized/eliminated, and the extraction rate of renewable resources is adjusted to suitable values.
Adjusting outputs from the system to absorption rates
Output of technological waste is minimized/eliminated, and the emission rate of biological waste is adjusted to suitable values.
Closing the system Connection of the waste management stage to the resource acquisition stage.
Maintaining resource value within the system Improvement of products' durability and recirculation of resources through different stages of products' life cycles.
Reducing the system's size, the total amount of resources that circulate within the system is reduced; Overall improvement of the global production–consumption process.
Designing for CE shift from a linear production–consumption model into a circular one.
Educating for CE change in education, values, and behaviors of producers and consumers: new consumption culture and paradigm.

Weetman C.
Waste = food, in living systems, there is no such thing as "waste"–one species' waste becomes food for another species.
Build resilience through diversity, use of diversity to strengthen the overall health of the system, creating resilience.
Use renewable energy, use renewable energy sources in all CE processes.
Think in systems, connections between ideas, people, and places to create opportunities for people, planet, and profit.

Tonelli M., Cristoni N.
Green-tech and responsible use of resources, switch to renewable energy sources. Virgin raw material extraction is reduced to a minimum.
Maximize utilization rate, assets are exploited fully by maximizing their utilization rates.
Product and materials at the highest utility, development of capabilities to set up circular flows of materials and products.
Minimize and phase out negative externalities, gradual achievement of zero negative environmental externalities (water/air pollution, soil degradation).

(Pesce, et al, 2020)

EU Recycling rate of e-waste 2017, an interesting and useful insight into the views and thinking of those who responded.

EU Recycling rate of e-waste 2017 – chart created online data set no longer available.

Issue	Barriers
Marketing	➢ Lack of confidence in refurbished equipment ➢ Lack of shop premises to increase sales ➢ Bad publicity regarding fraud and identity theft ➢ Lack of customers for bulk volume sales
Legislation	➢ Manufacturers obligated WEEE takeback services ➢ Equipment held in lease arrangements means companies cannot donate without breaching contracts ➢ Legislation aimed at curtailing rouge reuse firms drive up licensing fees ➢ Companies are reluctant to pass products on for reuse because of concerns about data security
Processing of WEEE	➢ Time intensive processing time ➢ Vast range of technical knowledge required in order to process the variety of appliances received
Collection and transport of WEEE	➢ High fuel and potentially high collection costs ➢ Practical and logistical factors, including distance travelled to collect WEEE ➢ Limited collection capacity ➢ Companies not wanting to pay for collection services offered
Supply	➢ Lack of access to large quantities of quality equipment ➢ Organisations upgrading equipment less regularly ➢ Equipment stripped of vital components before donation ➢ Difficulties in obtaining operating system disks to go with computers ➢ Too few equipment in good condition
Costs	➢ Time/cost of refurbishment verses final item cost ➢ Low value of some used equipment ➢ Company's perception of item value ➢ Lack of awareness of residual value
Storage	➢ Limited storage space for equipment ➢ Poor storage/handling can lead to damaged and broken equipment
Staffing	➢ Low staff numbers

Table 10: Barriers to Reuse operations (modelled on; Ongondo, et al, 2013)

No	Title	Date
1	Towards the Circular Economy Vol. 1 An economic and business rationale for an accelerated transition	January 25, 2012
2	Towards the Circular Economy Vol. 2: Opportunities for the consumer goods sector	January 25, 2013
3	Towards the Circular Economy Vol. 3: Accelerating the scale-up across global supply chains	January 24, 2014
4	A New Dynamic: Effective business in a circular economy	January 30, 2014
5	Growth Within: A circular economy vision for a competitive Europe	June 25, 2015
6	Delivering the Circular Economy: A toolkit for policymakers	June 26, 2015
7	Towards the Circular Economy: Business rationale for an accelerated transition	December 02, 2015
8	The New Plastics Economy: Rethinking the future of plastics	January 19, 2016
9	Intelligent Assets: Unlocking the circular economy potential	February 08, 2016
10	A new Dynamic 2: Effective systems in a circular economy	February 25, 2016
11	Circular Economy in India: Rethinking growth for long-term prosperity	December 05, 2016
12	The New Plastics Economy: Catalysing action	January 16, 2017
13	Achieving 'Growth Within'	January 20, 2017

14	Book: The Circular Economy: A wealth of Flows – 2nd Edition	January 30, 2017
15	Urban Biocycles	March 28, 2017
16	Cities in the circular economy: An initial exploration	August 29, 2017
17	A New Textiles Economy: Redesigning fashion's future	November 28, 2017
18	The New Plastics Economy: Rethinking the future of plastics & catalysing action	December 13, 2017
19	Circular Consumer Electronics: An initial exploration	April 23, 2018
20	The Circular Economy Opportunity for Urban and Industrial Innovation in China	September 19, 2018
21	Artificial Intelligence and the Circular Economy	January 23, 2019
22	Cities and Circular Economy for Food	January 24, 2019
23	Circular Economy in Cities	March 04,2019
24	Reuse – Rethinking Packaging	June 12, 2019
25	Completing the Picture: How the Circular Economy Tackles Climate Change	September 23, 2019

Table 12: Ellen Macarthur Foundation Publications (Source – EMF6, 2020)

Indicator	Calculation Methods
1. Single Indicator	
(a) Mineral Resource Comprehensive Utilization Rate (MRCUR)	MRCUR = 0.7 x total recovery rate of major mineral resources + 0.3 x comprehensive utilization rate of associated mineral resources
(b) Primary Resource Productivity (PRP)	PRP = GDP (constant prices)/total consumption amount of major primary resources (petroleum, natural gas, coal, iron ore, non-ferrous metal ore, non-metallic resources and biomass resources, among which petroleum, natural gas and coal are all fossil fuels, in apparent consumption)
(c) Secondary Resource Recycling Rate (SRRR)	SRRR = 0.5 x industrial solid waste comprehensive utilization rate + 0.3 x renewable resource recycling rate + 0.2 x industrial water recycling rate
(d) Environmental Efficiency (EE)	EE = GDP (constant prices)/total discharges of major pollutants (the sum of COD, ammonia nitrogen, SO_2, smoke, dust and solid waste)
2. Comprehensive Indicator	
(e) Comprehensive Circular Degree (CCD)	CCD = ∑ (MRCUR + REE + SRRR)/3
3. Supplementary Indicator	
(f) Total recovery rate of major mineral resource	The data are obtained from governmental reports and published articles
(g) Comprehensive utilization rate of associated mineral resources	The data are obtained from governmental reports and published articles

(h) Comprehensive utilization rate of industrial solid wastes	Comprehensive utilization rate of industrial solid waste = volume of comprehensive utilization rate of industrial solid waste/produced volume of industrial solid waste x 100%
(i) Recycling rate of major renewable resources	Recycling rate of major renewable resources = (domestic waste iron and steel recovery amount/crude steel production + domestic waste non-ferrous metals recovery amount/production of 10 major non-ferrous metals + domestic waste plastic recovery amount/primary plastic production + domestic waste paper recovery amount/machine-made paper production + scrap cars recovery amount/production of cars + waste electronic and electric products recovery amount/production of electronic and electric products) x 1/6 x 100%
(j) Industrial water recycling rate	Industrial water recycling rate = recycling amount of industrial water/ (new industrial water consumption + recycling amount of industrial water) x 100%
(k) Resource Environmental Efficiency (REE)	Resource environmental efficiency = (total consumption amount of major primary resources – total discharge of major industrial pollutants)/total consumption amount of major primary resources x 100%
(l) Index of mineral resource comprehensive utilization rate	Index of mineral resource comprehensive utilization rate = current year mineral resource comprehensive utilization rate/ base year mineral resource comprehensive utilization rate x 100%

(m) Index of primary resource productivity	Index of primary resource productivity = current year primary resource productivity/base year primary resource productivity x 100%
(n) Index of the secondary resource recycling rate	Index of the secondary resource recycling rate = 0.5 x index of industrial solid waste comprehensive utilisation rate + 0.3 x Index of renewable resource recycling rate + 0.2 x Index of industrial water recycling rate
(o) Index of industrial solid waste comprehensive utilization rate	Index of industrial solid waste comprehensive utilization rate = current year industrial solid waste comprehensive utilization rate/ base year industrial solid waste comprehensive utilization rate x 100%
(p) Index of renewable resource recycling rate	Index of renewable resource recycling rate = current year renewable resource recycling rate/base year renewable resource recycling rate x 100%
(q) Index of industrial water recycling rate	Index of industrial water recycling rate = current year industrial water recycling rate/base year industrial water recycling rate x 100%
(r) Index of environmental efficiency	Index of environmental efficiency = current year environmental efficiency/base year environmental efficiency x 100%

Table 13: Evaluation indicator system of the Circular Degree of the National Economy in China (based on Hu, et al, 2018)

Year	Winter	Spring	Summer	Autumn
1659		8	15	9.3
1660	2	8.7	15	9.7
1661	5	8.3	14.7	10.7
1662	5.7	8.3	15	10
1663	1.7	7.3	14.7	10
1664	4.7	8	15.7	9.3
1665	2	7.3	15	9.3
1666	3.7	8.3	16.7	10.3
1667	2.3	6.3	16	9.3
1668	4.3	7.7	15.3	10
1669	3.3	7.7	16	10
1670	2	8	15.3	10
1671	3.5	8	15	9.3
1672	2.3	8	15	9.7
1673	3.7	7.8	15.2	8
1674	2.5	6.5	13.7	8.7
1675	2.8	6.8	13.7	7.7
1676	5	7.7	16.8	7.5
1677	2	8.2	15.3	8.7
1678	1.8	7.2	15.3	9.8
1679	1	7.8	16.2	9.2
1680	3.2	7.7	14.7	10.5
1681	1	7.5	15	10.7
1682	3.7	7.5	14.5	9.3
1683	3.8	8.8	15	8
1684	-1.2	7.5	15.5	8.7
1685	2.7	8.7	14.3	10
1686	6.3	9.3	15.5	9.5
1687	4.7	7.3	14.5	9.3
1688	3.7	6.5	14.5	7.7
1689	2.7	8	14.3	8.7
1690	4.3	7.3	14.7	9.3
1691	2.2	7.2	15.2	8.3
1692	1.8	6.8	14.5	7.7
1693	3.8	6.2	14.8	9.2
1694	2.7	6.7	13.7	7.8
1695	0.7	6	13.2	8.7
1696	4.7	6.5	14.7	8.7
1697	1.3	8	14.3	8.3
1698	1	6.5	14	8.7
1699	3.4	6.8	15.5	9.4
1700	3.3	7.3	14.5	8.9
1701	3.2	6.1	16.2	9.5
1702	5.1	7.4	14.8	9.6

1703	3.5	8.6	15.4	8.5
1704	3.5	8.4	16	8.9
1705	3.4	7.8	15.1	8.2
1706	3.8	9.2	16.1	9.9
1707	3.7	8.2	16.3	9.7
1708	4.5	8.8	15.3	10.2
1709	1.2	8	15.2	10.3
1710	3.2	8	15	10.3
1711	4.8	8.7	15.3	9.8
1712	3.8	7.8	15.3	9.5
1713	4.2	6.8	14.2	9.3
1714	4.5	7.5	15.8	9.8
1715	4.3	9	14.8	10.3
1716	0.8	8	15	9.2
1717	3.3	7.7	14.8	9.5
1718	3.2	8	16.2	9.8
1719	3.8	7.8	16.7	9.8
1720	4	7.5	14.7	9.5
1721	3.8	7.2	15.2	9.7
1722	4.5	8	14.7	10.4
1723	3.1	9.4	15.3	10.6
1724	5.2	7.8	15.5	9.4
1725	3.7	8	13.1	9.7
1726	3.1	8.7	16	10.3
1727	3.7	9.3	16.2	10
1728	3.3	9.3	16.4	9.7
1729	1.7	6.7	15.9	11.6
1730	4.6	9.1	15.2	11.8
1731	2.5	8.3	16.2	11.8
1732	4.7	8.8	15.7	10.6
1733	5	9	16.5	9.5
1734	6.1	9.5	15.5	9.3
1735	4.1	8.5	14.8	10.3
1736	5	8.7	16.6	10.6
1737	5.6	9.1	15.7	9.7
1738	4.7	8.9	15.5	9.7
1739	5.6	8	15.3	8.8
1740	-0.4	6.3	14.3	7.5
1741	2.8	6.9	15.8	11.2
1742	3.1	7.1	15.5	8.6
1743	3.4	8	15.8	10.8
1744	3.1	7.4	15.4	9.7
1745	3.2	7.8	14.4	10.1
1746	2.2	7.6	15.3	8.4
1747	4.8	7.6	16.6	10.2

1748	3.2	6.2	15.3	10.2
1749	5	8.1	14.9	10.2
1750	5.1	8.9	15.5	9.5
1751	3.2	7.5	14.9	8.4
1752	3.1	7.6	15.4	10.3
1753	3.3	8.5	15.2	9.2
1754	3.5	7.4	14.7	10
1755	2.3	7.8	15.1	8.9
1756	4.3	7.3	14.9	9
1757	2.4	7.9	15.9	9.5
1758	3.2	8.7	15.1	8.6
1759	5.2	8.9	16.5	9.8
1760	2.7	9.2	16	10.2
1761	5.8	9.4	15.5	9.9
1762	4.4	8.9	16.7	8.7
1763	2.6	8.2	15.1	9.1
1764	4.6	7.8	15.1	8.6
1765	2.7	8	14.9	8.8
1766	1.4	7.3	15.3	9.9
1767	2.9	7.3	14.4	10.1
1768	3	8.3	15.2	8.8
1769	3.3	8	14.8	8.9
1770	4.4	6	14.7	9.4
1771	2.6	6.9	14.8	9.2
1772	2.9	7	16.4	10.6
1773	3.8	8.4	15.9	9.2
1774	2.9	8.6	15.6	9.2
1775	4.7	9.5	16.4	9.5
1776	2.2	8.9	15.2	9.8
1777	2.9	8.6	14.9	10.6
1778	2.6	7.8	16.5	8.8
1779	5.6	9.7	16.6	10.6
1780	1.4	9	16.2	9.7
1781	3.4	9.3	17	10.4
1782	4.2	6.1	14.9	7.7
1783	3.2	7.9	16.5	9.6
1784	1.2	7.3	14.3	9.4
1785	1.4	7.3	15.4	9.3
1786	3	7.1	15.4	7.5
1787	4.1	8.6	15.1	9
1788	3.8	8.9	15.7	9.8
1789	2.1	7.3	15.3	8.8
1790	5.7	8.1	15	9.5
1791	4.4	8.9	15.3	9.5
1792	2.6	8.7	15.1	9.2

1793	3.9	7.1	15.4	9.7
1794	4.8	9.5	16.4	9.4
1795	0.5	7.5	15	10.7
1796	6.2	8.2	14.8	9.1
1797	2.6	7.7	15.6	8.5
1798	4.1	9.5	16.5	9.4
1799	2	6.1	14.6	8.9
1800	2.1	8.5	16.1	9.5
1801	4.2	9	16	9.7
1802	2.3	8.4	14.8	9.7
1803	2.9	8.6	15.8	8.6
1804	4.4	8.3	15.9	10.5
1805	2.8	8.2	15.2	9.2
1806	4	8	15.5	10.6
1807	4.4	7.5	16.1	8.3
1808	2.4	7.6	16.6	8.6
1809	3.3	8.1	14.5	9.2
1810	3.3	7.4	14.8	9.7
1811	3.1	9.6	14.9	11.2
1812	3.7	6.6	13.8	9.1
1813	3.1	8.7	14.4	8.3
1814	0.4	7.2	14.3	8.5
1815	3.7	9.3	14.8	9
1816	2.4	6.8	13.4	8.7
1817	4.7	7.3	14.3	9.6
1818	3.2	7.6	16.6	11.6
1819	4.1	9	15.7	8.9
1820	1.4	8.3	14.7	8.7
1821	3.5	8.2	14.5	11.3
1822	5.8	9.6	16	10.4
1823	1.5	8	13.6	9.3
1824	4.6	7.6	14.8	10.1
1825	4.3	8.6	15.9	10.4
1826	3.8	8.8	17.6	9.7
1827	2.7	8.9	15.2	10.7
1828	5.7	9.1	15.6	10.6
1829	4	7.8	14.8	8
1830	1.1	9.5	14.2	9.7
1831	2.7	9.3	16.3	10.7
1832	4.1	8.4	15.5	10.1
1833	4	8.9	14.9	9.6
1834	6.5	9.3	16.2	10.4
1835	4.7	8.6	16.1	9.6
1836	3.4	8	15.1	8.5
1837	3.8	5.6	16	9.4

1838	1.4	7.2	15	9
1839	3.6	6.9	14.6	9.7
1840	3.8	8.3	14.6	8.1
1841	1.6	9.3	13.8	9.1
1842	3.1	8.5	15.7	8.6
1843	4.4	8.2	14.3	9.3
1844	4.3	8.4	14.5	9.5
1845	1.5	6.7	14.2	9.2
1846	5.8	8.7	17.1	10.4
1847	1.7	8.2	15.5	10
1848	4.1	9.3	14.6	9.4
1849	5.1	8.2	15	9.7
1850	3.5	7.9	15.4	9.2
1851	5	7.9	14.8	8.9
1852	4.8	8	15.9	9.5
1853	4.5	7.3	14.6	9.2
1854	3.1	8.7	14.6	9.6
1855	1.9	6.4	15.3	9.4
1856	3.8	7.3	15.2	9.3
1857	3.8	8	16.5	11
1858	4.2	7.8	15.8	9.5
1859	5.1	8.8	16.4	9.1
1860	2.3	7.4	13.5	8.5
1861	2.7	8.1	15.2	9.7
1862	4.3	8.9	13.8	8.8
1863	5.7	8.6	14.8	9.6
1864	3.7	8.6	14.4	9.5
1865	2.7	8.7	15.8	10.9
1866	5.3	7.8	15.2	10.1
1867	4.7	7.9	15.1	9.2
1868	4.5	9.7	16.9	9.2
1869	6.8	7.8	15.3	10
1870	3	8.5	16.1	9
1871	2.4	9.1	15.1	8.6
1872	5.2	8.2	15.5	9.5
1873	4.1	7.7	15.3	8.9
1874	4.9	8.8	15.4	9.9
1875	2.8	8.7	15	9.7
1876	4.1	7.3	16	10
1877	5.9	7	15	9.2
1878	5	8.7	16	9
1879	0.7	6.4	13.7	8.5
1880	2.5	8.2	15.2	9
1881	2.3	8.1	14.6	9.6
1882	5.1	9.1	14.4	9.2

1883	4.8	6.9	14.6	9.6
1884	5.5	8.3	15.9	9.7
1885	4.4	7	14.6	8.5
1886	2.4	7.4	15.1	10.5
1887	2.7	6.3	16.1	7.8
1888	2.5	6.7	13.7	9.3
1889	3.7	8.2	15.1	9.4
1890	4	8.3	14	9.9
1891	1.5	6.5	14.6	9.7
1892	3.3	7.2	14.3	8.6
1893	2.9	10.2	16.5	9.3
1894	4.4	8.5	14.5	9.6
1895	1.2	8.6	15.3	10
1896	4.4	9.2	15.6	8.1
1897	3.8	7.9	15.9	9.9
1898	5.4	7.7	15.1	11.2
1899	5.8	7.6	16.9	10.2
1900	3.1	7.4	15.8	10.2
1901	4.3	8.1	15.8	9.5
1902	3.2	7.7	14.3	9.7
1903	5.3	8.2	14.2	10
1904	3.6	8	15.2	9.1
1905	4.2	8.3	15.5	8.1
1906	4.4	7.6	15.6	10.7
1907	3.1	8.1	13.6	10
1908	4.1	7.6	14.9	10.7
1909	3.4	7.8	13.9	9
1910	4.2	8.2	14.7	8.8
1911	5	8.5	17	9.8
1912	5.1	9.4	14.3	8.5
1913	5.3	8.6	14.7	11.1
1914	5.2	8.9	15.5	10.1
1915	4.3	8	14.8	8.4
1916	5.5	7.7	14.5	10.1
1917	1.5	7.1	15.5	9.8
1918	4.2	8.5	14.9	8.9
1919	3.9	8.1	14.6	7.8
1920	5.6	9.1	14	10.1
1921	5.4	9	16.2	10.5
1922	4.9	7.6	13.7	8.8
1923	5.7	7.8	15.1	8.5
1924	3.9	7.5	14.4	10.2
1925	5.8	8	15.7	8.5
1926	4.7	8.6	15.6	9.5
1927	4.2	8.8	14.7	9.7

1928	4.4	8.6	14.8	10.2
1929	1.7	8.1	14.9	10.5
1930	4.6	8.1	15.4	10.1
1931	3.8	7.8	14.7	9.4
1932	4.8	7.4	15.8	9.4
1933	4.1	9.4	17	10.2
1934	3.2	8	16.2	10.4
1935	6.1	8.2	16.3	10
1936	3	8.3	15.4	9.8
1937	5.4	8.3	15.7	9.6
1938	4.6	9.1	15.3	11.2
1939	4.7	8.7	15.4	10.4
1940	1.5	9.1	15.7	9.8
1941	2.6	7	15.7	10.5
1942	2.2	8.5	15.5	9.6
1943	5.9	9.6	15.6	10.1
1944	4.3	8.9	15.7	9.3
1945	3.7	10.1	15.7	11.2
1946	4.5	8.6	14.7	10.6
1947	1.1	8.6	17	10.9
1948	5.1	9.6	14.8	10.4
1949	5.6	8.8	16.5	11.5
1950	5.1	8.8	15.9	9.4
1951	2.9	7	15	10.7
1952	3.9	9.9	15.7	7.9
1953	3.5	8.5	15.4	10.7
1954	4.1	8.2	14.1	10.5
1955	3.5	7.4	16.5	10.1
1956	2.9	8.3	14.1	9.9
1957	5.5	9.5	15.6	9.9
1958	4.2	7.4	15.3	10.8
1959	3.6	9.8	16.6	11.5
1960	4.6	9.4	15.4	10.2
1961	4.9	9.7	15	10.7
1962	3.6	6.9	14.4	9.5
1963	-0.3	8.4	14.8	10.7
1964	3.5	8.8	15.1	10.1
1965	3.3	8.3	14.5	9.3
1966	4.4	8.2	15	9.8
1967	5.1	8.4	15.5	9.9
1968	3.5	8.1	15.1	11
1969	3.2	7.3	15.7	10.8
1970	3.3	7.8	15.9	11
1971	4.4	8.1	15	10.4
1972	4.9	8.4	14.2	9.5

1973	4.9	8.2	15.6	9.8
1974	5.4	8.3	14.8	8.9
1975	6.4	7.7	16.9	9.9
1976	5.2	8.3	17.8	10.1
1977	3.3	8.2	14.4	10.6
1978	4.1	8.3	14.5	11.5
1979	1.6	7.5	15	10.5
1980	4.6	8.2	14.8	10.1
1981	4.5	9	15	10.3
1982	2.6	8.8	15.9	10.8
1983	4.3	7.8	17.1	10.6
1984	4.2	7.6	16.3	10.9
1985	2.7	8	14.5	9.9
1986	2.9	7.3	14.8	10
1987	3.5	8.2	14.8	9.9
1988	5.3	8.8	14.8	9.6
1989	6.5	9	16.5	10.9
1990	6.2	9.6	16.2	10.7
1991	3	8.9	15.5	10.6
1992	4.6	9.9	15.7	9.5
1993	4.7	9.2	14.9	8.5
1994	4.7	8.8	16.2	11
1995	5.9	8.8	17.4	11.4
1996	3	7.4	15.8	10.4
1997	4	9.6	16.6	10.9
1998	6.1	9.6	15.2	10.6
1999	5.4	9.9	15.9	11.4
2000	5.4	9.2	15.7	10.7
2001	4.5	8.5	16.1	11.4
2002	5.4	9.6	15.8	11
2003	4.7	9.7	17.3	10.5
2004	5.1	9.3	16.2	11
2005	5.2	9.2	16.2	11.5
2006	4.1	8.6	17.2	12.6
2007	6.4	10.1	15.2	10.7
2008	5.6	9.1	15.4	10.1
2009	3.5	9.7	15.8	11.5
2010	2.4	8.5	15.9	9.8
2011	3.1	10.2	14.8	12.4
2012	5.1	9.1	15.2	9.8
2013	3.8	6.9	16.3	10.8
2014	6.1	10	15.9	12.1
2015	4.5	8.7	15.3	11
2016	6.7	8.6	16.4	10.8
2017	5.4	10.3	16.1	

Member State	2014	2015	2016	Overall
Belgium	19	14	22	18
France	19	13	21	18
Netherlands	18	13	20	17
Luxembourg	18	13	20	17
Austria	17	14	19	17
Germany	18	13	20	17
Sweden	18	13	21	17
Denmark	16	13	18	16
United Kingdom	17	13	17	16
Ireland	16	13	17	15
Malta	16	8	20	15
Spain	15	11	17	14
Czech Republic	16	9	19	15
Finland	14	10	17	14
Slovakia	13	9	20	14
Portugal	14	10	15	13
Greece	13	10	15	13
Estonia	17	10	12	13
Cyprus	11	10	16	12
Romania	13	8	16	12
Italy	13	9	14	12
Poland	14	8	16	13
Lithuania	13	8	17	13
Latvia	18	7	14	13
Croatia	13	8	14	12
Hungary	12	7	15	11
Slovenia	12	8	14	11
Bulgaria	12	6	12	10

Table 15: The Seasons Data

Horizon 2020 applications per Member State 2014 to 2016

Success rates of Horizon 2020 Applications per member state

Member State	2014	2015	2016	Overall
Belgium	19%	14%	22%	18%
France	19%	13%	21%	18%
Netherlands	18%	13%	20%	17%
Luxembourg	18%	13%	20%	17%
Austria	17%	14%	19%	17%
Germany	18%	13%	20%	17%
Sweden	18%	13%	21%	17%
Denmark	16%	13%	18%	16%
United Kingdom	17%	13%	17%	16%
Ireland	16%	13%	17%	15%
Malta	16%	8%	20%	15%
Spain	15%	11%	17%	14%
Czech Republic	16%	9%	19%	15%
Finland	14%	10%	17%	14%
Slovakia	13%	9%	20%	14%
Portugal	14%	10%	15%	13%
Greece	13%	10%	15%	13%
Estonia	17%	10%	12%	13%
Cyprus	11%	10%	16%	12%
Romania	13%	8%	16%	12%
Italy	13%	9%	14%	12%
Poland	14%	8%	16%	13%
Lithuania	13%	8%	17%	13%
Latvia	18%	7%	14%	13%
Croatia	13%	8%	14%	12%
Hungary	12%	7%	15%	11%
Slovenia	12%	8%	14%	11%
Bulgaria	12%	6%	12%	10%

The key laws and Regulations for Circular Economy implementation in China

Primary Laws and Regulations for CE Implementation in China

Date of Issue	Law and Regulations	Authority for Issue
1985	The Interim Provisions on The Development of Resources Comprehensive Utilization	The State Council of China (No.117,1985)
1996	The Views on Further Development of Resources Comprehensive Utilization	The State Council of China (No.36,1996)
2003.12.17	The Views on Speeding up The Clean Production	State Environmental Protection Administration (China SEPA), The National Development and Reform Commission (NDRC), etc., 9 sectors.
2004.01.12	The Catalog of Comprehensive Utilization of Resources	The National Development and Reform Commission (NDRC), Ministry of Finance, State Bureau of Taxation
2004.12.29	Law of the People's Republic of China on the Prevention and Control of Solid Waste Inducing Environmental Pollution	The Standing Committee of the National People's Congress (NPC)
2006.11.27	The National Key Industry Clean Production Technology Oriented Directory	The National Development and Reform Commission (NDRC); State Environmental Protection Administration (China SEPA)
2008.08.29	Circular Economy Law of The People's Republic of China	The Standing Committee of the National People's Congress (NPC)
2012.02.29	The Cleaner Production Promotion Law of the People's Republic of China (2012 Revised)	The Standing Committee of the National People's Congress (NPC)
2013.01.23	Circular Economy Development Strategy and the Recent Action Plan	The State Council of China
2004.09.24	The Ordinance on Construction of Ecological City Based on Circular Economy in Guiyang City The first regulation issued by a municipal government in China）	The Standing Committee of Guiyang People's Congress (NPC)

(Zhou, et al, 2014)